# A FIRST BIOLOGY

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By

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# FOREWORD

When Dr Elsie J. Cadman was preparing the manuscript of this book she asked me to write a foreword to it. She died a few weeks after the manuscript was completed, and it has fallen to me to select the figures and to see it through the press.

The book is designed as an introduction to Biology suitable for children of about twelve to fifteen years of age, and is based on her long experience of teaching. Dr Cadman encouraged practical work in her teaching, and the book is intended as a guide to the pupil both in the schoolroom and in the countryside.

It was almost her last wish that the book should be published, and I sincerely hope that it will help to inculcate in children an interest in the lives of animals and plants, and be a valuable introduction to Human Physiology.

Malcolm Wilson

*University of Edinburgh*, 1951

# NOTE

The opportunity of a second edition has been taken to make a number of minor amendments. An Index has also been added in response to requests from teachers using the book.

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## CHAPTER I

# INTRODUCTION

MEANING OF BIOLOGY – DIFFERENCES BETWEEN LIVING AND NON-LIVING OBJECTS – DIFFERENCES BETWEEN PLANTS AND ANIMALS – FUNCTIONS WHICH LIVING THINGS HAVE TO PERFORM

### Meaning of Biology

As the title of this book indicates, its purpose is to introduce you to the study of Biology, and before you go further it is essential to understand clearly what is meant by the word Biology. It is derived from two Greek words, 'bios,' meaning life, and 'logos,' meaning word. One dictionary states that the original meaning of the word 'Biology' was 'discoursing about life.' This would cover a very wide field and would have appealed to the ancient Greeks, who delighted in lengthy talks on every conceivable subject. In another dictionary Biology is defined as 'the science which deals with the living functions and activities of both plants and animals,' and this is the meaning of the term which has been kept in mind during the preparation of this book. Biology, therefore, is *the study of everything connected with the life of plant or animal*, e.g. how it 'breathes' or respires, grows, moves and produces individuals like itself. To understand how these functions are performed the structure of plant and animal will have to be examined.

### Differences between Living and Non-living Objects

Since Biology is the *Science of Life*, we must first study the meaning of the word *life* itself. By non-living objects you must clearly understand that we do not mean plants and animals which are dead, that is which have had life and no longer possess it. It is only those objects which have never had life and cannot be included in the plant or animal kingdom that are regarded as non-living objects.

The following may be taken as the main differences between living and non-living objects, though, as you go further into the study of Biology, you may find that there are exceptions to nearly every one.

(1) *Living things can move, non-living things are unable to move.* Exceptions to this difference can be found quite readily. You, yourself, can make a stone move by throwing it, but the stone does not move of itself; you have made it move. A more striking exception will be found when you come to use the microscope. Tiny, solid, non-living particles, so small that they are only visible when very highly magnified, may often be seen to have a dancing movement, called 'Brownian movement' after the man who discovered it. Any movement of a non-living object must be directed by a living organism or it is purposeless. The movement of a living object, on the other hand, is directed towards a useful end—for example, a plant may move to climb round some support, and an animal moves in search of food. It would be well, here, to distinguish between *movement* and *locomotion*. By simple movement let us understand any movement which is carried out by plant or animal without leaving the place in which it is situated. By locomotion is meant movement to a new position. This is more characteristic of the typical animal than of the typical plant.

(2) *Irritability.* Living things respond to outside influences, non-living things do not. If you touch the head of your pet tortoise it will probably withdraw its head into its shell, unless it has got to know you very well. In this way the tortoise makes use of its shell for protection. The broad bean plants you are growing in the classroom window bend towards the light and the leaves may make use of it during the manufacture of food.

(3) *Respiration.* All living things respire continually. The process of respiration will be described fully in a later chapter.

(4) *Nutrition and Growth.* Living things are able to obtain food and to use it in building up their bodies. Non-living things cannot do this. As a result of the food taken in, the young animal or plant is enabled to grow or increase in size. The food taken in must be changed in form so that it can be built up into the structure of the plant or animal.

When you make crystals of alum or of copper sulphate in the laboratory you will notice that they increase in size, but this is only because the solid alum or copper sulphate dissolved in the water becomes deposited on the surface of the crystal and so causes it to increase in size.

(5) *Reproduction.* Living plants and animals have the power of giving rise to offspring like themselves. Non-living things have not this power. As you will see in later chapters, there are many interesting ways in which this process of reproduction is carried out.

### Differences between Plants and Animals

All living things belong either to the plant or the animal kingdom. These kingdoms have gradually developed from very simple one-celled plants and animals to the more complex—for example, flowers and man. You will understand this much better when you have completed your course in Biology. All I want you to realise now is that when one is dealing with the simplest plants and animals it is not always easy to distinguish as to whether they belong to the plant or animal kingdoms. Exceptions can be found to each of the following distinctions, but they will form a foundation upon which to build.

(1) *Animals have power of locomotion; plants, as a rule, do not have this power.* Generally, animals can move freely from one place to another, while plants are fixed. There are exceptions to this rule for some simple animals, e.g. the corals and sponges are fixed, while some simple plants have the power of locomotion, at least during a large part of their existence.

(2) *Nutrition of plants and animals differs widely.* Plants contain green colouring material called *chlorophyll*, the presence of which enables them, in sunlight, to manufacture food-stuffs, such as starches and sugars, from the water in the soil and the carbon dioxide in the atmosphere. Animals do not possess chlorophyll, and so are unable to manufacture simple food-stuffs for themselves. They must rely upon plants and other animals for their food supply. With this method of nutrition is connected the power of locomotion possessed by animals. They have to move about in search of their food, while the plant has its sources of food surrounding it.

All plants are not green—for example, the common mushroom does not possess chlorophyll and therefore has to rely upon dead plants and animals for its food supply, and there are some plant-like animals which contain chlorophyll. Here is one of the difficulties in deciding whether certain organisms belong to the plant or animal kingdom. The expert has to weigh up the plant- and animal-like characters of these puzzling organisms and decide whether plant- or animal-like characters are more numerous. For example, the plant-like animal, Euglena, possesses chlorophyll; but this is its only distinctly plant-like character, whilst it has several animal-like characters and is generally described in a zoology textbook, not in one on botany.

(3) The plant relies for its *rigidity* upon its cell structure. The plant body is built up of a great number of minute, brick-like cells. These cells are kept firm by a constant supply of water, and so they build up a rigid structure which is sufficiently strong to resist the breezes which blow over the plant. Very often the walls of the plant cells are specially strengthened and so aid in keeping it firm and upright.

Most animals have either an external or an internal skeleton to give them the required support, and the animal cell has usually a very thin cell wall. Those animals which have no firm skeleton are generally small and live surrounded by water. Being protected by the water they have no need for a supported skeleton.

## Functions which Living Things have to Perform

In concluding this chapter, it must be emphasised that all living things have the following functions to perform. They must *respire*, *feed*, *grow*, *respond to external stimuli*, *excrete waste material* and *reproduce*. These functions and the manner in which they are performed will be considered in the following chapters.

## CHAPTER II

## STRUCTURE OF A TYPICAL PLANT

Shepherd's Purse – External Structure of Root, Stem and Leaf – Functions of each Part – Flower of Lesser Celandine – Structure and Uses of each Part – Comparison with Flower of Primrose

### A Typical Flowering Plant

In commencing our study of Biology let us dig up a plant of Shepherd's Purse or any other typical flowering plant, and examine each part (Fig. 1). Carefully wash all soil from the roots and you will at once see that the part below ground, the *root*, and the part above ground, the *shoot*, differ very markedly in colour. The root is white or pale brown, whilst most of the rest of the plant is green.

**The Root.** The root is white in colour because it is the part of the plant which grows below ground and is not exposed to the light. In the shepherd's purse there is a principal or main root which grows downwards into the soil and is called a *tap* or *primary* root. This may become forked if it should encounter a stone or other obstacle round which it has to grow. From the tap root smaller roots arise called *secondary roots*, because they are formed after the tap or primary root. Primary and secondary roots form a branching mass of roots known as a *tap root system*.

In some plants, e.g. the grasses, the primary root dies off very early and its place is taken by a number of fibrous roots which arise just above it in the young seedling. These form a *fibrous root system*, and it is equally effective in spreading through the soil.

*Functions of the Root.* The root has two very important duties to perform.

(1) As the root system spreads through the soil it obtains a footing for the plant and anchors it firmly so that it is not readily uprooted.

(2) Grow some cress on a piece of damp blotting-paper and you will see a number of tiny, silky hairs near the tip of the

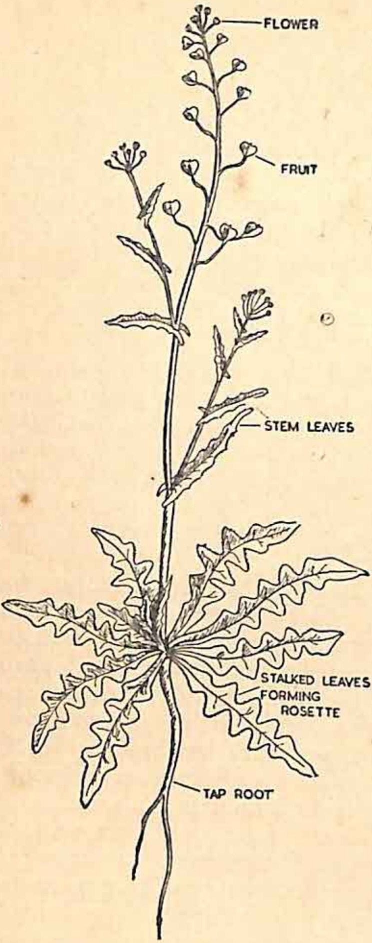


FIG. 1. Shepherd's Purse.

root. These are called *root hairs*, and they are one of the most important parts of the plant, for it is through them that the plant takes in a great part of its food supply in the form of the water present in the soil and the simple salts dissolved in the water. These simple salts, when united with the sugars and starches formed from water and carbon dioxide, help to form the more complex proteins and other substances which build up plant and animal bodies.

**The Shoot.** The shoot is made up of a number of different parts, stem, leaf and flower. Each of these has special duties to perform and is adapted to carry them out efficiently.

**The Stem.** In the shepherd's purse the stem is erect and green in colour. On it are borne the leaves and the flowers. In some plants, e.g. goose-grass or cleavers, the stem is weak and unable to stand erect, so it scrambles over the other plants in the hedgerow instead of relying on its own strength.

*Functions of the Stem.* Like the root the stem has two important duties to perform.

(1) The erect stem of the shepherd's purse and the scrambling stem of the goose-grass alike enable the flowers and leaves to obtain the light they need to obtain their full development.

(2) Place some willow twigs in water containing a little red ink and leave for one or two days. Cut across the stem, and you will see that there are little red streaks passing up through it. If there are leaves on the willow twigs you will find that the veins have become tinged with pink.

The above experiment can be repeated using a white flower such as a chrysanthemum instead of the willow twigs. In a few days the petals become delicately veined with pink.

Both experiments prove that the water taken in by the plant travels upwards through the stem to the leaves and flowers. The streaks shown in the willow stem show further that the water only passes up certain parts of the stem. Down certain parts of the stem, different from those up which the water with its dissolved salts passed to the leaves, the manufactured food-stuffs pass to every part of the plant. The stem provides passages up which water and dissolved salts pass to the leaves, and other passages down which manufactured food passes to every part of the plant which requires it.

**The Leaf.** In the shepherd's purse the leaf is flat with an upper and a lower surface. The leaves are of two kinds. Those lower down the plant are larger and have short stalks. They often form a rosette round the stem of the plant just above ground-level. This *rosette habit* is very useful, because the thick covering of leaves shuts out the light from any seedlings which may be growing beneath and so they cannot flourish, and the plant has less competition in the struggle for existence.

The margins of the lower leaves are deeply indented, but those of the upper leaves are entire and the leaves themselves have no stalks. They are attached directly to the stem as if they sat right on it, so they are said to be *sessile*.

*Functions of the Leaf.* The leaf is one of the most important parts of the plant and it has several essential duties to perform.

(1) The green cells of the leaf form a great kitchen or laboratory in which sugars and starches are manufactured from the water which has entered from the soil and the carbon dioxide which has entered from the air. These sugars and starches unite with the simple salts which have entered from the soil to form more complex substances which are finally built up into the body of the plant or animal.

(2) If the leaf is examined carefully under the microscope little *pores* will be found present on the lower surface.

Through these pores air containing oxygen and carbon dioxide is taken in. Some of the oxygen is used up in respiration and some of the carbon dioxide in food manufacture. The air that remains passes out through the pores and fresh air enters to take its place. It must be understood that the pores are not the only entrance and exit for air in every leaf. If the skin of the leaf is provided with a thin covering, instead of the waxy covering found on the holly leaf, a certain amount of air may enter directly through the skin. It must also be realised that the leaf is not the only part of the plant which respires. Every part of the plant, root, stem and flower, as well as leaf, have to respire. The green stem respires in the same way as the leaf. The young root is able to take in air over its entire surface because it has a very thin covering. The older stem and root, which are covered with a corky layer, have special organs through which the air enters.

(3) Through the same pores on the lower surface of the leaf water passes out in the form of water vapour. The salts in the soil can only enter the root in very weak solution, so that much more water is taken in than the plant requires for food manufacture or for keeping its cells firm. The water not required must pass out or the cells of the plant will become too full and will rupture.

Sometimes, in the morning, you may have noticed that each grass-leaf has a tiny drop of water at its tip. This water has passed up through the plant during the night and is oozing out as liquid water through a specially large pore at the tip of the leaf. Very often, in the morning, nasturtiums have little drops of water present round the edges of the leaves, for there is a specially large pore at the end of each vein.

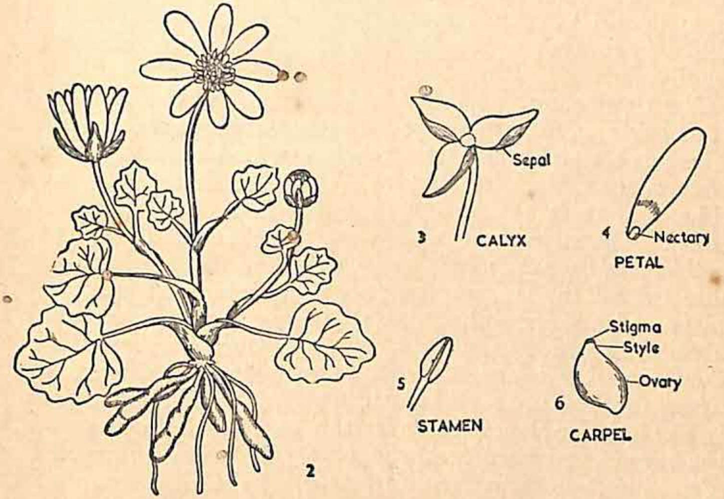
**The Flower.** The most important use of the flower is to produce the fruit and seed and to protect them until they are ripe. You will find from examination of the Lesser Celandine and Primrose flowers how they are constructed to perform this duty.

### The Lesser Celandine

The flower of the Lesser Celandine (Fig. 2) is made up of a number of different parts arranged roughly in *whorls* or rings.

**The Calyx.** The outermost whorl consists of three boat-shaped structures called *sepals* (Fig. 3). The sepals are green in colour and are strongly made, and they protect the inner parts of the flower when it is a bud. Each sepal is free from its neighbour. They often wither and drop off early, after their work has been accomplished when the flower is in bloom.

**The Corolla.** The corolla is the whorl just inside the calyx. It is made up of a varying number of *petals*, usually from seven to eleven. The petals are of a bright, buttercup-yellow colour, and their shape is not unlike that of the sepals. They are a little flatter and more oval in shape, and are also free from each other (Fig. 4). The bright colour attracts bees to come from another flower, bringing with them the pollen which has been dusted on to them. Down each petal run distinct lines, which some botanists call honey guides, leading to the nectar which is formed at the foot of the petals. The flower often has a pleasant smell, which is also attractive to the bee.



FIGS. 2–6. Lesser Celandine. 2. Whole plant; 3. Calyx; 4. Petal; 5. Stamen; 6. Carpel.

**The Andrœcium.** Inside the whorl formed by the petals is a large number of *stamens*. It would probably take some time to count them, though one industrious pupil found that there were thirty-eight in his flower. The number varies in different flowers of the Lesser Celandine, and it is usually said that the Lesser Celandine has an indefinite number of stamens.

Each stamen is very minute and must be examined with a pocket-lens (Fig. 5). It consists of two parts, a head and a stalk. The head is called the *anther* and the stalk the *filament*. The anther is filled with a great number of tiny grains which can only be made out with the aid of the high-power microscope. The grains form a fine yellow dust called *pollen*. The main use of the anther is to produce pollen. The filament holds the anther up so that the bee can get at the pollen readily.

**The Gynœcium.** This is the innermost part of the flower. It consists of a large or indefinite number of small green structures which again must be examined carefully with a pocket-lens. Each small green structure is called a *carpel* (Fig. 6). It consists of three main parts, *stigma*, *style* and *ovary*. The stigma produces a sticky substance to which the pollen adheres when it is brought to the flower. The style, just behind the stigma, is not a very important part of the carpel. Its use is to hold the stigma up so that it can readily obtain the pollen from the bee. Sometimes, as in the Lesser Celandine, the ovary is so big comparatively that this is not necessary, and the style is almost entirely absent. The ovary is the large swollen portion at the base of the carpel. It is the most important part of the carpel, for in it the seed is formed and protected until it is ripe. In the diagram you see the single *ovule*, as the structure is called, which will later form the seed when fusion has taken place with the contents of the pollen grain. The carpels of many other flowers, as we shall see, contain more than one ovule.

## The Primrose

Let us now compare the flower of the Primrose with that of the Lesser Celandine. Try to hunt for primroses yourself, and you will find, if you look carefully, that there are two kinds of primrose plants (Fig. 7). Be sure to bring in both kinds to examine in the laboratory. On some plants you will find that there is a small green ball in the throat of the flower, whilst in flowers on other plants there are five small yellow bundles. The green ball is the stigma, and the yellow bundles are stamens. The flower with the stigma showing is called the pin-eyed flower, because the stigma is like the head of a pin. The flower with the stamens showing is called the thrum-eyed flower, because the stamens look like bundles of carpet thrums.

**The Calyx.** In both kinds of Primrose the calyx is the same in structure. It is made up of five green sepals joined to form a calyx cup.

**The Corolla.** The corolla is also the same in structure in both kinds of flower. It consists of five yellow petals, the lower portions of which are joined to form a corolla tube, while the upper portions spread out in a heart-shaped manner.

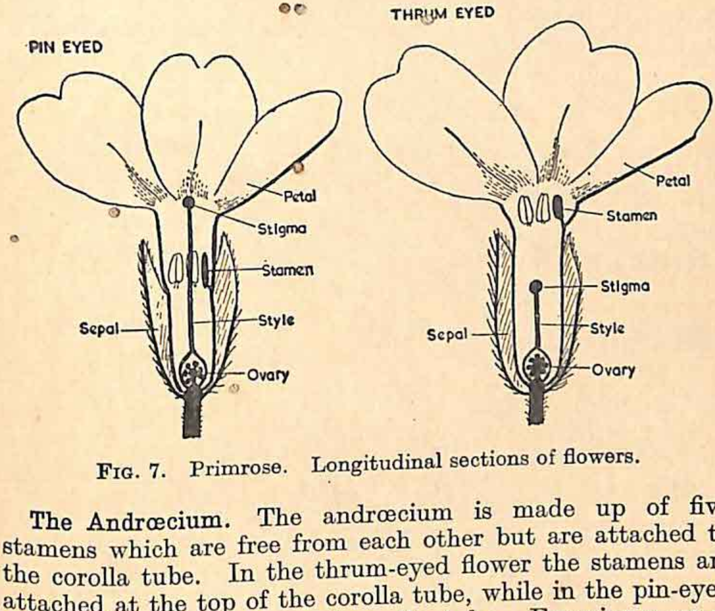


Fig. 7. Primrose. Longitudinal sections of flowers.

**The Andrœcium.** The andrœcium is made up of five stamens which are free from each other but are attached to the corolla tube. In the thrum-eyed flower the stamens are attached at the top of the corolla tube, while in the pin-eyed flower they come half-way down the tube. Examine some of the pollen from each flower under the microscope and you will find that the pollen grains of the thrum-eyed flower are bigger than those of the pin-eyed flower.

**The Gynœcium.** Experts who have investigated the flower very carefully are able to tell us that the gynœcium is made up of five carpels joined together; but it would be very difficult for us to find out this fact for ourselves. The five stigmas are joined together to form a single ball-like stigma, which is placed at the top of the corolla tube in the pin-eyed flower and half-way down in the thrum-eyed flower. The pollen grains from the thrum-eyed flower will only stick to the stigma of the pin-eyed flower; they are too big to stick to the stigma of the thrum-eyed flower. In the same way the pollen grains of the pin-eyed flower will only stick to the stigma of the thrum-eyed flower; they are too small to stick to the stigma of the pin-eyed flower.

The five styles in each kind of flower are joined together to form a single large style. In the pin-eyed flower the style is long, in the thrum-eyed flower it is much shorter.

The five ovaries are also joined together to form a single large ovary which contains a large number of ovules. These develop later into tiny seeds which are very easily blown about by the wind.

## CHAPTER III

# EXTERNAL FEATURES AND LIFE-HISTORY OF TWO ANIMALS

Frog – Aquarium – Egg – Tadpole – Adult Frog – Movement – Respiration – Nutrition – Reproduction – Comparison of Frog with Toad and Newt – Earthworm – Wormery – External Features – Movement – Respiration – Nutrition – Reproduction – Use to Man

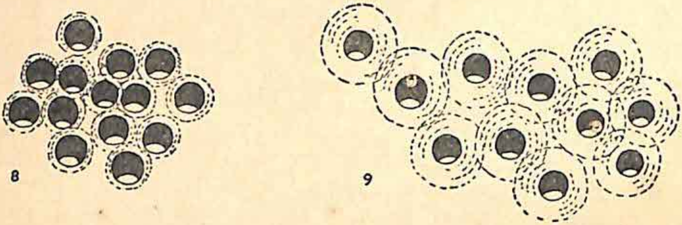
### The Frog

In the early spring, from about the middle of February to the middle of March, depending upon the season and the part of the country in which you are living, you may have seen and heard frogs in their hundreds coming to the surface of a nearby pool or pond. They are coming up, after their winter sleep at the bottom of the pond, to mate and to lay eggs.

Collect some frog spawn, which you will find floating on the top of the pond, and bring it in to examine and to watch its development.

**The Aquarium.** You can easily set up an aquarium in which the frog spawn will hatch out, the tadpoles will develop and young frogs will be produced. Choose the largest glass dish or jar that you can obtain. If there is a glass pneumatic trough in the laboratory that is the very thing, since it is more satisfactory if there is a wide surface of water exposed to the air so that the air may dissolve in the water to a greater extent. For this reason, also, a shallow dish is better than a deep one. Place some stones which have been scrubbed in hot water in the foot of the dish, put the spawn in and keep it near a window, but not in direct sunlight, as this is bad for the young tadpoles. When the water becomes overheated they often die. Each morning a beaker full of water should be taken out of the dish and a beaker full of fresh water added. This adds fresh air as well as water, so that the developing tadpoles are enabled to breathe more readily. Care should be taken that the fresh water added is at the temperature of the room. Very cold water gives the young tadpoles a shock and retards their development. The beaker of fresh water should be left standing on the bench for at least an hour before it is added to the aquarium.

**The Egg.** The frog spawn (Fig. 8) consists of a very large number of eggs, the structure of which can be made out with the aid of a pocket-lens. Each egg consists of a dark central ball surrounded by a layer of jelly. The jelly protects the dark specks in the centre of the eggs from rubbing against each other, and so becoming damaged. It may also protect them from other animals in the pond. The jelly is of very little use as food for the tadpoles and must be removed from the aquarium soon after the eggs have hatched out, as otherwise it will decay and foul the water. When the eggs are laid the envelope of jelly is quite thin, but after it has been in the water for an hour or two it increases considerably in size, due to the fact that it takes in water readily (Fig. 9).

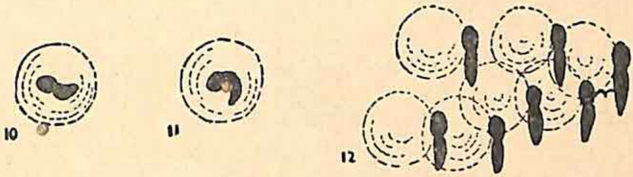


FIGS. 8–9. Frog Spawn. 8. Eggs recently laid; 9. Jelly around eggs has become swollen.

On the side of the small black ball in the centre of the egg is a white speck. If the egg has been freshly laid this speck is quite big, but apparently it soon decreases in size, for the black centre grows down over it and soon hides a large part of it. The white speck is the heaviest part of the black centre, so tends to pass to the lower surface and, therefore, is sometimes not easily seen. This white speck is the yolk of the egg and forms a store of food for the developing tadpole.

*Hatching of the Egg.* About a fortnight after the spawn is laid, or perhaps only a day or two after it has been brought into the laboratory, changes begin to take place inside the egg. The black central speck commences to elongate and then a constriction appears, dividing it into two parts (Fig. 10). This is known as the *dumb-bell* stage. Soon a second constriction appears and head, body and tail of the young tadpole are clearly visible. By this time the tadpole has elongated so much that it has to curl up inside the egg (Fig. 11). It now begins to wriggle its way out of the protective jelly, and finally emerges to commence active life.

**Development of the Young Tadpole.** For two or three days after it has emerged from the jelly the young tadpole hangs motionless to the jelly from which it has come, or to any water weed present, or even, sometimes, to the side of the aquarium (Fig. 12). During this time feathery outgrowths appear at each side of the head. At first there are two pairs (Fig. 13), but later a third pair is formed. These are the external gills, through which the tadpole respires during the first part of its life. The tadpole leaves the weed or jelly to which it has been clinging and begins to move about actively. It can now be seen that a mouth has developed so that the young animal is able to feed on the water weed present. It is a good plan to bring in some of the weed from the pond where the spawn was obtained and place it in the aquarium as food for the tadpoles at this stage.

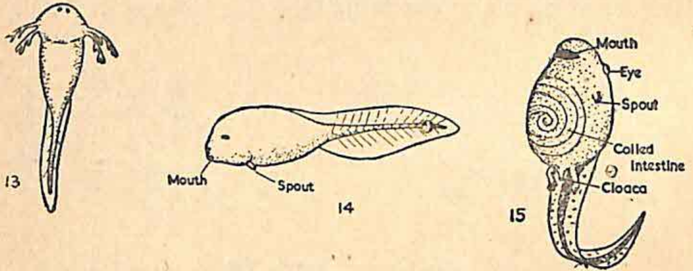


Figs. 10–12. Hatching of Frog's Eggs. 10. Tadpole in dumb-bell stage; 11. Tadpole showing head, body and tail; 12. Tadpole has emerged from jelly.

In a few days the external gills disappear. Those on the right side of the head disappear first, and this gives the tadpole a curious, lopsided appearance. I well remember the excitement in one of my classes when they first watched the gills disappear. 'The tadpoles are eating each other,' some of them cried. 'They have eaten the gills all off one side.' You should watch carefully for this stage as it does not last long.

The gills on the left side disappear very soon after those on the right side, and where they once were a little hole called the *spout* is formed. Meantime, internal gills have been formed, and it is through these that the tadpole respires during the next part of its life. The spout forms a connection between these gills and the water outside (Fig. 14).

The tadpole has now attained its mature form and, during the next month, it continues to grow in size. It has a round mouth with fringed, horny jaws, a pair of eyes, and a long, muscular tail by means of which it swims about actively. If a tadpole is held up to the light and examined a coiled food canal can be made out, starting at the mouth and ending at a little hole just below the point where tail and body join (Fig. 15). This hole is the exit of a cavity called the *cloaca*, and through it both solid and liquid waste material pass out from the body.

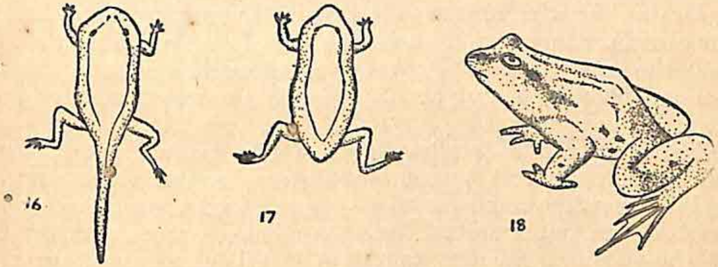


FIGS. 13–15. Development of Tadpole. 13. With two pairs of gills; 14. With spout; 15. Fully developed tadpole.

**Transformation of Tadpole into Frog.** About two months after the tadpole has hatched out of the egg the wonderful series of changes resulting in its transformation into a frog commences. On each side of the tail, just where it joins the body, small outgrowths appear which rapidly develop into the jointed hind legs. Each of these ends in five toes which are webbed so that the frog can swim more readily (Fig. 15).

The hind legs continue to grow for two or three weeks, and then the final stages of the great transformation commence. At this time the tadpole becomes very quiet and does not eat much. It retires to the bottom of the pond for a day or two, and becomes so weak that it falls an easy prey to the younger, stronger tadpoles. It may be advisable to remove the developing frogs to another aquarium so that they are out of danger. It can now be seen that the forelegs have been formed under the fold of skin covering the upper part of the frog's body. They were formed about the same time as the hind limbs, but were not readily seen because they were hidden under the skin. The forelimbs end in *four* toes which are *not* webbed and they do not take such an active part in swimming. The young frog pushes out its left foreleg through the spout and its right foreleg through the skin, and it sheds the outer layer of skin (Fig. 16).

If a young frog at this stage is examined, it will be found that during its transformation from a tadpole to a frog the following changes have taken place. The body has become longer and thinner, tapering towards the tail end. The head is flatter and the round mouth has become slit-like; the horny fringe round the jaws has disappeared. The eyes are much more prominent and larger, so that the frog is able to see better when it is on land. The tail soon disappears and is absorbed into the body of the frog as food (Fig. 17).



FIGS. 16–18. Transformation of Tadpole into Frog. 16. With legs and tail; 17. Loss of tail; 18. Young frog.

The frog has now attained its final shape (Fig. 18). It is still very tiny, and it will be three or four years before the animal becomes mature and able to produce spawn. During this part of its life the frog lives partly on land and partly in the water. On land it is able to leap from place to place by means of its powerful hind legs, and in water it can swim. During the winter the frog hibernates in the mud at the bottom of the pond and comes to the surface in the following spring.

Now let us consider more closely some of the main life processes which the frog has to carry out so that it may live.

**Respiration.** During the early stages of its life the tadpole respires by means of external gills. The water surrounds these gills so that it is easy for the oxygen dissolved in the water to be absorbed and the waste carbon dioxide to be liberated.

Later, internal gills are formed. The water passes through the mouth, over the gills, where the oxygen is absorbed and carbon dioxide liberated, and out at the spout.

Just before the tadpole commences to change into a frog it will be noticed that it comes more and more frequently to the top of the water to gulp in air. This is because lungs are now being formed and the air dissolved in the water is not sufficient; atmospheric air must be obtained. Finally, when the transformation is complete, the young frog respires very largely by means of lungs, and has to come to the surface frequently for air. A certain amount of air passes through the mucous membrane lining the mouth and also through the skin.

During the winter, when the frog is hibernating, it respires very little. In its mud hole the supply of air is limited, but the frog gets all it requires through its skin. The young, developing tadpole in the egg also respires through its skin.

**Nutrition.** In its earliest days of life the young tadpole relies upon the yolk present in the egg for its food supply. Later, when the mouth with its strong, horny jaws has been formed, the young animal feeds voraciously on the pondweed in the vicinity. In the aquarium it will also eat pieces of meat and hard-boiled egg, but these are not at all necessary. The tadpole will flourish quite well without them, and they are inclined to foul the water if left in it for more than an hour. A quite satisfactory diet consists of watercress, with the addition of a few ants' eggs or a little dried *Daphnia* procured from a livestock shop. The tadpoles seem to thrive rather better when *Daphnia* is used.

When the young frog has developed it is wise to transfer it from the aquarium to the nearest pond. The frog lives almost entirely on insects, which it catches alive by flicking out its tongue; it does not like dead insects. The tongue is attached to the front of the mouth for this purpose. If not supplied with a suitable diet the frog will perish.

**Reproduction.** Frogs are three or four years old before they begin to pair. When the frogs leave the pond in the spring those old enough soon begin to mate. The male frog is smaller than the female. He jumps on to her back, and as she moves back towards the water he clings very tightly so that he is not knocked off. When she reaches the pond she goes, with the male attached, to the bottom and lays her eggs there. The male immediately pours over them thousands of tiny bodies called *sperms*. These sperms can be compared with the contents of the pollen grain in the flower, as you will see later. Sperms and eggs unite, and it is the fertilised eggs which you have brought into the laboratory.

**Comparison of Frog with Toad and Newt.** Try to bring in some toad and newt spawn and compare with that of the frog. The spawn of the frog is laid in large masses, but that of the toad is laid in a long string. The spawn of the newt is very difficult to find. Each egg is laid singly and covered with bits of water weed and other debris which adhere to its sticky coat.

The tadpoles of frog and toad are similar in shape and development, those of the toad being smaller and almost black in colour. The tadpoles of the newt are larger and much paler than those of frog and toad. The external gills of the newt remain during almost the entire life of the tadpole, and forelimbs instead of hindlimbs appear first.

The mature toad can be distinguished from the mature frog, because it is rather squatter in shape and the skin is covered with warts instead of being smooth. The newt is longer and slimmer than toad or frog, and it never loses its tail.

### The Earthworm

The earthworm lives in *burrows* in the upper layers of the soil. It makes these burrows by pressing the soil apart with its pointed head, and patting it together with its flattened tail-end. If the soil is too hard to push aside, the earthworm actually eats it, passing it through the food canal and out at the cloaca in the form of the worm-casts which are such a familiar sight on a lawn. There are several suggestions as to why they are called worm-casts, but perhaps the most reasonable is that they resemble the worm closely in appearance.

The worm rarely leaves its burrow except during the night. Even at night it often puts out only its head and a portion of its body, while the tail remains fixed in the burrow so that retreat is readily accomplished. It is during the night that the worm usually feeds, and it may move about from one place to another in search of a better feeding-ground. During the winter it remains asleep in a little chamber at the foot of its burrow.

The earthworm has no eyes, ears or nose, but it is sensitive to light and to vibrations. If one seeks for worms at night

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with a lantern it may be possible to see them retreat into their burrows when the light shines on them. Worms like to come to the surface when it is raining, and some birds, for example the thrushes and seagulls, imitate the patter of the raindrops on the soil, so that the worm is deceived and the bird obtains a meal.

In a broadcast lesson some time ago the following interesting story was told. The broadcaster noticed that each morning there was a circular path where the dewy grass of his garden had been pressed down by tiny footsteps. He watched carefully to find out the culprit, and discovered that it was a small hedgehog. The hedgehog ran lightly round in circles and the worms, thinking that it was raining, came to the surface, thus providing food for the clever animal.

**The Wormery.** To study the habits of the earthworm you should make the following very simple *wormery*. Choose a large, deep glass dish and wash it out carefully. A glass with flat sides will give you a better chance of observing the formation of the burrows. Put a number of stones at the foot for drainage, and fill the dish with alternate layers of sand and soil, ending with a layer of soil, and making the layers of sand much wider than the layers of soil. Place some decaying leaves on the surface for food, and keep the soil damp by watering it occasionally.

The wormery should be kept in the dark; if not, the worms will not come to the sides of the dish and you will not be able to see their burrows. In a few days you will be able to make out that the layers of sand and soil are becoming mixed, showing the action the worm has on the soil in which it lives.

**External Features.** The earthworm (Fig. 19) is made up of 100 to 150 rings or segments, and a mature worm is usually about six inches in length. There is a sharply pointed head-end and a flat tail-end. At the head-end is the mouth with an overhanging upper lip, and at the tail-end is a hole called the *anus* through which the soil leaves the body of the worm.

On each segment are eight stiff bristles set in pairs. These can be readily felt if the worm is gently passed through the fingers from tail to head. Watch the worm moving, and you will see that it is by means of these bristles that it is enabled to do so. The worm first releases its head-end, leaving the tail-end attached to the soil by means of the bristles, then it stretches out as far as it can and fixes the head-end. It next releases the tail-end and brings it up as near as possible to the head-end. This process is repeated as often as required, and so the worm is enabled to move from place to place. The worm can move up tail-end to head-end, and vice versa, by means of strong muscles just under the skin.

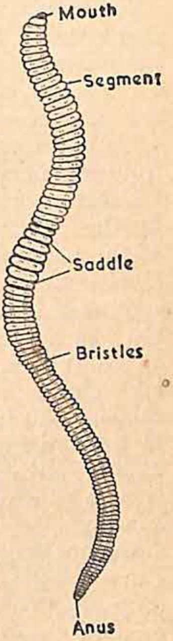


FIG. 19.
The Earthworm.

Watch the movements of the worm on a piece of rough brown paper. Listen carefully and you will hear the rustle of the bristles against the paper. Place a heap of soil on the brown paper and observe how rapidly the worm makes for it and burrows into its depths. Compare the movements of the worm on a piece of smooth glass.

Some distance down from the mouth is found a swollen portion called the *saddle*. This is especially obvious during spring, when the eggs are laid, and its use will be discussed later; it is often more brightly red in colour than the rest of the body.

Down the back of the worm runs a row of important *pores*, but these are so small that they are invisible to the unaided eye. From these pores oozes out a fluid which bathes the skin and keeps it moist. The fluid also kills any germs which might be harmful to the worm.

**Respiration.** The worm takes in oxygen and gives out carbon dioxide over the whole surface of its skin. To enable it to do this the skin must be kept moist. If the surface soil becomes dry the worm burrows down to the moister layers. If the worm becomes too dry it dies but, on the other hand, it drowns in deep water.

**Nutrition.** The earthworm lives upon dead and decaying leaves of all kinds. The great scientist, Charles Darwin, who spent years studying these interesting animals, found that the worm prefers leaves with a strong smell, such as onion and garlic, if it can get them. These leaves are taken in at the mouth and crushed up and digested as they pass, with the soil, down the food canal to the anus. Waste material, which the worm cannot make use of as food, passes out with the soil.

If the supply of dead leaves is scarce the worm eats a great deal of soil, and uses the decaying plant and animal remains in it as food. As a result a large amount of soil has to be passed through the food canal and out at the anus, abundant worm-casts being formed.

**Reproduction.** Like the frog the earthworm produces eggs and sperms, but, unlike the frog, every worm can produce both eggs and sperms. There are no male and no female worms. The sperms, however, do not unite with the eggs of the same worm. When they mate, the worms lie side by side and exchange sperms, so that the eggs always unite with sperms from another worm.

After mating, a band of india-rubber-like material is formed by the saddle. This band becomes quite free from the body of the worm and the latter commences to wriggle out of it. During its passage the worm deposits firstly eggs, secondly sperms from another worm, and finally some liquid food in the band. The worm then wriggles quite free, and the band closes at each end to form a *cocoon*. Inside the cocoon eggs and sperms unite and the young worms are formed. The cocoons can often be found when you are digging for worms in the spring. They are oval in shape, white in colour, and about ¼ inch in length. Only one worm emerges from each cocoon as a rule; any others formed have added to its food supply.

**Use to Man.** The earthworm is of the greatest use to man. Darwin called it Nature's Ploughman. In passing the soil down its food canal the worm breaks up the particles and renders them more suitable for plant growth. Plant food material is mixed with the soil which, therefore, is rendered more fertile. Air spaces are formed so that plant roots can respire and water is allowed to enter the soil more readily. It is interesting to learn that no worms are present in the soil of the great wheat-growing districts of Canada. The person who gave me this information could not say whether there was any other animal there which did the work of Nature's Ploughman.

Darwin carried out several interesting experiments to show that worms turn up large amounts of soil. He found that the number of worms normally present in arable land can bury anything left on its surface under one inch of soil in five years. Sometimes the rate may be greater. When he was a young man he strewed the surface of a field near his home with pieces of chalk. Thirty years after, he went back to find that the worms had buried the chalk under at least seven inches of soil.

Some time ago at the famous abbey of Beaulieu a beautiful tesselated pavement was revealed. This was hidden when the abbey was destroyed in the time of Henry VIII, nearly four hundred years ago. During this time the worms had buried the pavement under a layer of soil at least one foot deep and so it has been preserved.

## CHAPTER IV

## STRUCTURE AND LIFE-STORIES OF SOME MORE ANIMALS

Cabbage White Butterfly – Stages in Life-story – House-fly – Honey-bee – Fish – Aquarium – External Features – Movement – Respiration – Rough Dissection of Food Canal and Brain – Reproduction – Bird – Migration – External Features – Adaptations for Flight – Respiration – Nutrition, and Adaptations for Obtaining Food – Reproduction

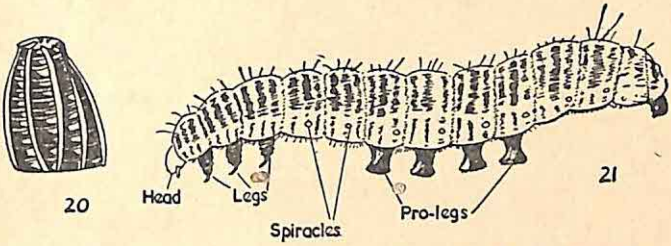
### The Cabbage White Butterfly

**The Egg.** During the month of May, if you examine the under surfaces of some cabbage leaves, you will very probably find clusters of the tiny yellow eggs which belong to the *Cabbage White Butterfly* (Fig. 20). Bring some of the leaves into the laboratory and place the stalks in water in a glass jar; a lamp glass should be fitted over the top of the jar to keep the air surrounding the leaves moist.

**The Larva or Caterpillar.** In about three weeks the eggs hatch out and give rise to small green caterpillars (Fig. 21). These feed voraciously on the cabbage leaves and must be provided daily with a fresh supply of food. They grow very rapidly until they are about two inches long. The skin soon becomes too small and the creature moults, discarding the old skin and forming a new one beneath. The process of moulting is repeated four or five times during the caterpillar stage.

The caterpillar should be examined with a pocket-lens. It has a *head*, the most important parts of which are the *mouth*, with its hard, horny jaws, and the *spinneret* beneath the mouth. From the spinneret come silken threads which fasten the caterpillar to the leaf. If a strong hand-lens is used three small dots, black in colour, may be made out on each side of the head. These are called *eye-spots* and they are sensitive to light.

The rest of the caterpillar is divided into thirteen segments, which are green in colour and spotted with black. Along the back runs a bright yellow streak. On the first three segments there are *true, jointed legs*, which end in claws, but on five of the other segments there are unjointed, flat legs provided with hooks, which grip the cabbage leaf firmly. These are generally known as *pro-legs* or *cushion feet*. The segments with the true legs form the *thorax* or chest part of the caterpillar, the remaining segments form the stomach part or *abdomen*. The pro-legs are found, one pair on each of the first four abdominal segments and one pair on the last abdominal segment.



FIGS. 20–21. Cabbage White Butterfly. 20. Egg (*enlarged*); 21. Caterpillar (*slightly enlarged*).

Along each side of the yellow strip a line of small holes can be made out. These are called *spiracles*, and it is through them that the caterpillar takes in the air necessary for respiration.

**The Pupa or Chrysalis.** In two or three weeks, when the caterpillar is fully grown, it leaves the leaf on which it has been feeding. Before this happens the glass jar containing the cabbage leaves should be removed to a specially prepared cage, with one side fitted with fine wire gauze. The caterpillar climbs by means of silken threads to a corner of the cage. In nature it would leave the leaf and climb up on to the stem of the plant upon which it had been feeding. There it fastens itself securely with more silken threads.

After a few hours the skin of the caterpillar splits and a new form, the *pupa* or *chrysalis* emerges (Fig. 22). The word pupa is the same as the French word *pupée*, a doll. You will see later why this name is very appropriate. The word chrysalis comes from the Greek word *chrusos*, gold, because the sheath is very often greenish gold in colour.

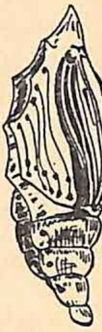
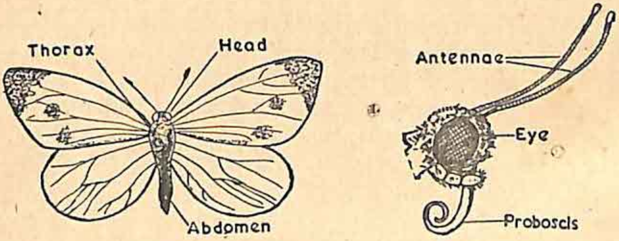


FIG. 22. The Chrysalis of the Cabbage White Butterfly (*slightly enlarged*).

The skin of the pupa soon becomes hard and firm, but it remains thin and transparent. Within the skin the body of the caterpillar has been broken down and built up again into another form. Eyes and wings can be made out clearly. The shape is just that of a doll-like form of the butterfly which is soon to emerge, hence the name pupa.

**The Imago or Butterfly** (Fig. 23). In about three weeks the skin of the pupa splits down the back and the butterfly emerges. In the cabbage white butterfly this is a very short-lived stage, for the butterflies live only a few days. There are male and female butterflies, and you may have seen them dancing about in pairs in the sunlight, lightly touching each other now and then. It is a pair mating. When they touch, he is giving her the sperms which she requires to render her eggs fertile.



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FIGS. 23–24. The Cabbage White Butterfly.
23. The imago; 24. The head, enlarged.

Place a mature butterfly in a jar containing some crushed laurel leaves, or in any other jar which has been prepared for killing insects. The insect will very quickly die and you can then examine it closely. You will see that, like the caterpillar, it is divided into three portions, *head*, *thorax* and *abdomen* (Fig. 23).

The *head* bears a pair of compound eyes each made up of a great number of simple eyes joined together. There are also two feelers or antennæ which are sensitive and enable the insect to feel its way, and a long, curled tongue or proboscis with which it can sip nectar from the flowers (Fig. 24). In the butterfly the antennæ are club-shaped, but in its close relative, the moth, they are usually feathered.

The *thorax* is made up of three segments. To each of these a pair of jointed legs is attached and, in addition, from the two hinder segments two pairs of wings arise. These are white in colour, the front wings having black tips; in addition the female has two black spots on each fore-wing and one on each hind-wing.

The *abdomen* is slender and covered with black, hair-like scales. It is divided into a number of segments, and spiracles are present like those on the caterpillar. Through these the fresh air necessary for respiration can be taken in and passed into a system of narrow tubes which penetrate to every part of the insect's body. After it has been utilised the air passes out through the spiracles and a fresh supply enters.

The length of the life of the imago in the butterfly and moth varies in different species from a few days to several months. Recent observations seem to show that some of the larger butterflies migrate as do the birds, and there is evidence to prove that one or two of the larger kinds have actually crossed from America to this country.

The silkworm moth may be very easily cultivated and it illustrates the life-story just described. The eggs, which can be obtained from dealers, should be kept in a large box with a glass lid and a few holes bored in the sides to admit air. The larvae will eat lettuce leaves readily and pupate, forming a fine silky cocoon. From this the beautiful moths emerge.

## The House-fly

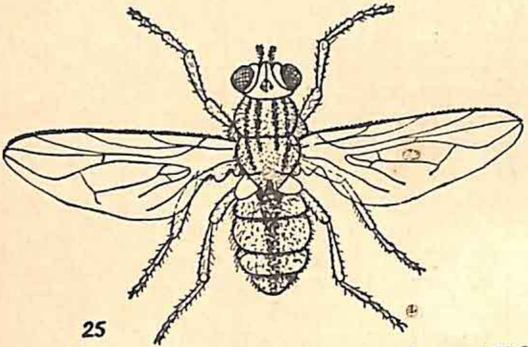
The House-fly (Fig. 25) is one of the most important insects for you to study because it can spread disease so widely. Its life-story is much like that of the cabbage white butterfly.

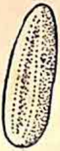
**The Eggs.** These are laid on manure heaps. They are tiny white specks about 1 mm. long (Fig. 26).

**The Larvæ or Maggots.** These hatch out of the eggs about 12–24 hours after they are laid. The maggot is white in colour and differs from the caterpillar because it has no true jointed legs, and can only crawl over the manure heap to feed.

**The Pupa.** In from four to five days the larva (Fig. 27) has reached its full size, ceases feeding and climbs to a dry place. The skin hardens and turns brown and the body contracts, becoming oval in shape. Marks of segments can be seen on the skin. This is the puparium or pupa-case, and in it the pupa is found (Fig. 28).

**The Imago.** In four or five days the fly emerges from the pupa-case and flies away. It has two short antennæ, large eyes, and a long hollow proboscis. There is one pair of wings. The second pair is replaced by two small club-shaped bodies, which are very difficult to see but which are important as they help the fly to balance. The body and legs of the fly are covered with hairs to which specks of disease-infested dirt readily adhere.





FIGS. 25–26. The House-fly. 25. Imago (*slightly enlarged*); 26. Egg (*enlarged*).

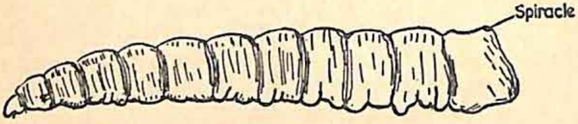


FIG. 27. The Larva of the House-fly (*slightly enlarged*).

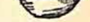


FIG. 28. The House-fly; pupa-case (*slightly enlarged*).

The fly lives in filthy surroundings, from which it comes to crawl over the food in the larder; it is one of the most common spreaders of disease. Watch it as it crawls over a lump of sugar. Down the long hollow proboscis comes a fluid which dissolves the sugar, and the solution is then sucked back into the body. During this process numerous disease germs have been deposited on the contents of the sugar basin.

There are three measures which should be taken to combat this peril:

(1) *Remove all refuse* which may form a breeding-ground for the fly, and see that it is kept some distance from the house, or in covered dust-bins.

(2) *Cover all food*, liquid and solid, carefully, so that the fly cannot touch it.

(3) *Kill all flies* by means of fly-papers, etc.

### The Honey-bee

The Honey-bee is another most interesting and important insect. Without it some of our most beautiful flowers and luscious fruits would not be so readily produced, and we should be deprived of the honey which many of us like so much.

The life-story is similar to that of the house-fly. Eggs are laid in the cells of the honeycomb. These hatch out into little white maggots or grubs which are fed and tended assiduously by the worker bees. The maggot feeds for about four days, moulting several times, and then lines its cell with a silken cocoon and pupates. A covering or 'sealing' is put over the cell by the worker bees, and the pupa remains for a fortnight undergoing the change into the imago. The young bee then bites its way through the 'sealing' and emerges. After preening and drying itself for about twenty-four hours it is ready to take up its duties in the hive.

Three kinds of bees are produced: *worker bees*, *drones* and *queens*. The drones are the male bees, and their purpose is to provide the queen with the sperms required to render her eggs fertile. In the autumn they are expelled from the hive and they do not use up the food supply laid by for winter.

The worker bees are female, but they rarely produce eggs. Cases have been known in which worker bees have laid eggs which produced drones. The worker bees carry on the work of the hive, and each has its special duties; some are nurses for the young grubs, some are scavengers, and others collectors of pollen and nectar.

The queen is a perfect female, and the only one which can lay eggs. There is only one queen in each hive, and she might have developed into a worker bee had she not been specially fed as a grub.

During the sunny days of summer the worker bees are busy collecting nectar and pollen from the flowers. They work so hard that, in about six weeks, they are quite worn out, but there are plenty of younger workers to continue. You will read more about their work in a later chapter.

Not only do the workers bring in pollen and nectar but they also collect resin, the sticky material which covers the buds of the horse-chestnut and oozes from the pine. This they use to varnish over the ends of the cells in the honeycomb, or cover over any decaying material which they are unable to drag out of the hive.

During the winter, the queen and those workers which survive, hibernate, living on the honey stored during the summer, or on sugar and water provided by the owner of the hive.

One of the most interesting events in the hive is the formation of a swarm. This usually occurs when the hive has become hot and stuffy due to overcrowding. Bees do not like the temperature to be too high. On a hot summer day you may often see certain of the workers sending a cooling current through the hive by fanning with their wings at the entrance.

When the swarm leaves the hive the old queen goes with it, and the workers left behind raise a new queen to take her place.

## The Fish

The fish is a great contrast to the insects which you have just been studying. The latter are adapted for life on the wing in the air, but the fish is adapted for life in the water. As you study its structure you will find that it has been most suitably constructed for this purpose.

**The Aquarium.** An aquarium, in which you can observe the movements and habits of fish, can readily be fitted up. Obtain a large square or rectangular glass tank. Perhaps you may be able to obtain a large glass accumulator jar from a friend who owns a garage.

Carefully wash some stones and sand in running water if possible. This can be done by placing the sand and stones in a deep basin and allowing water from a tap to trickle slowly over them for several days. If this is not possible the water should be changed frequently. Place a layer of the washed sand at the foot of the aquarium. Obtain some water plants from any ponds in your district, or from a dealer. Starwort

(*Callitriche*), Water Milfoil (*Myriophyllum*) and Canadian Waterweed (*Elodea*) are suitable plants to grow. Tie pieces of glass rod to the roots so that the plants will sink. Cover the roots with more of the washed sand and place the stones round the plants. If some water snails can be obtained they will help to keep the sides of the aquarium clean. Fill the aquarium almost to the top with water.

If the water weeds flourish there will be little need to trouble about the aeration of the aquarium, though it may be advisable to clean it out thoroughly once or twice a year.

If the aquarium can be arranged so that a constant slow current of water passes through it, it will be less necessary to grow water plants in it. The ways of arranging aeration vary considerably, and it is better for each teacher to select his own method according to local conditions. Remember that, if possible, no metal should be introduced into the aquarium, as this may be injurious to the fish.

The aquarium should be placed so that most of the light falls on the fish from above, as it would under natural conditions. Direct sunlight must be avoided, but the plants will not flourish unless they have a certain amount of light.

Leave the water standing in the aquarium for one or two days before introducing the fish, so that the water will attain the temperature of the room, and conditions will become settled and suitable for the fish.

If goldfish are being placed in the aquarium, keep them for a day or two in a *very* weak solution of Condy's fluid. They may be infected with the dread salmon disease, and the treatment will probably cure them in the early stages and also prevent the aquarium from becoming infected.

**External Structure.** Procure some ungutted haddock or herring from the fishmonger, and also ask him for a number of fish-heads. If you are lucky you may obtain heads of haddock, whiting or turbot.

As you will note from its streamlined shape (Fig. 29) the fish is well adapted for swimming rapidly through the water. If you feel its body you will find that it is slimy, and this enables the fish to slip through the water easily. The fish swims by vigorous strokes of its muscular tail. The fins aid in movement by alternately spreading and closing, while the side fins, particularly, are important in helping to maintain balance.

The head has a mouth with strong jaws, well provided with small sharp teeth. Teeth are also present on the roof of the mouth and further back on the throat. On the lower jaw in some fish, such as the haddock, there is a small barb.

The eyes of most fish, such as the haddock and herring, are placed one on each side of the head. They have no eyelids, as our eyes have, and the fish must sleep with its eyes open. Eyelids are not necessary, as the eye of the fish is always being bathed in water.

In some fish, such as the sole and flounder, the eyes are placed together on the same side of the head. This is a result of the habit which these fish have adopted of lying on their side on the sandy sea-floor in shallow water. Watch the flounder in an aquarium at a zoo or at a marine station, such as that at Millport. Notice its graceful, undulating movement as it glides over the sand. The young flounder started life with eyes one on each side of its head, and it swam in an upright position. Gradually, as it developed, one eye moved round till it was on the same side as the other, and the fish began to swim on its side. The mouth did not move with the eyes, but remained in its original position, and this gives the head a curious, twisted appearance.

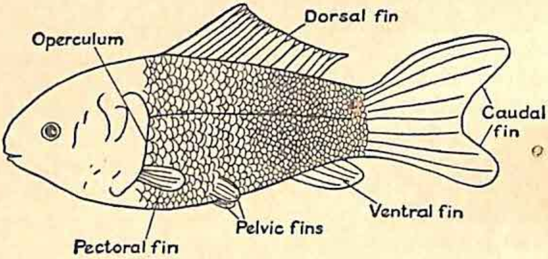


FIG. 29. The Goldfish.

On each side of the head are two openings in the middle line. These have nothing to do with respiration but enable the fish to smell.

The fish has an internal but no external hearing apparatus, and it is unlikely that it hears nearly as well as we do. Later you may be able to study its mechanism for hearing.

If you lift the flap which you will see where head joins body, you will find the gills. These, like those of the tadpole, are used for respiration (Fig. 30). The flap is called the *operculum*. The gills consist of arches of bone on which are projections called gill-rakers. The function of the gill-rakers is to prevent food taken in through the mouth being lost through the spaces between the gills, called the gill-clefts. On the arches soft membranous material is present, and this is the real 'breathing' material of the gill.

There are a number of *fins* arranged singly or in pairs. Along the back are the dorsal fins. There are three of these in the haddock but only one in the herring and goldfish. These are arranged singly. At the tail end is another single fin called the caudal fin. The word caudal comes from the Latin *cauda*, a tail. Along the belly are the ventral fins, two in the haddock but only one in the herring and goldfish.

There are two pairs of fins, the pectoral fins which correspond to our arms, and the pelvic fins which correspond to our legs.

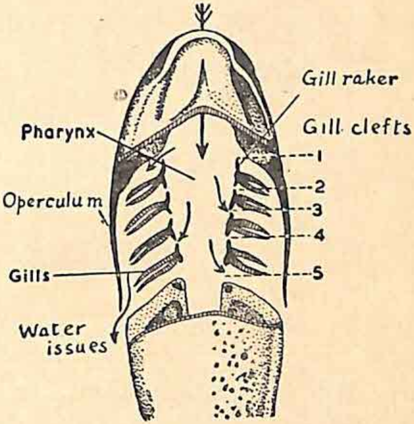


FIG. 30. The Respiratory Current in the Trout (*after* Ritchie).

The scales of the fish are easily detached for examination. They are developed to protect the skin. If examined under the lower powers of the microscope it will be seen that they are made up of a number of rings. By counting the number of these rings it is possible to make out the age of the fish.

Just near one of the ventral fins is found a set of openings which seem to form one large one. One of these openings is called the anus, and it is from this opening that the fish gets rid of waste food material which has not been digested.

**Simple Dissection.** For dissection you will need a few simple instruments, such as a sharp scalpel, a pair of scissors and some large pins. You will also need a flat dish into which some melted wax has been poured and allowed to solidify. The wax is sufficiently soft to allow pins to be pushed into it when it is necessary to pin down any part of the dissection.

Place the fish in the dish and cut along the belly from anus to mouth. Pin back the flaps of flesh. You will be able to make out the heart and the twisted food canal or intestine (Fig. 31). The heart has two main chambers, so it is simpler than our own, as you will see later. Perhaps you will be able to see some of the other internal features, but make sure of heart and food canal. Snip the food canal at the anus and carefully unravel it until you get nearly to the mouth. See if you can make out the stomach.

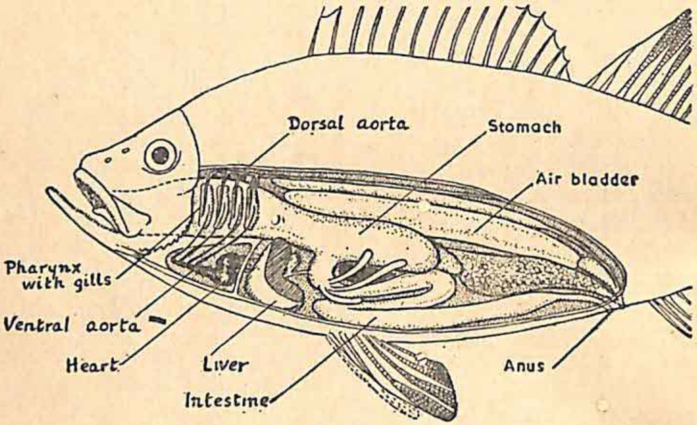


FIG. 31. Dissection of the Perch.

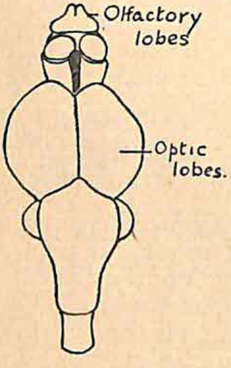


FIG. 32. The Brain of the Trout.

Place the fish with the belly downwards and pin carefully on to the wax. Remove the skin on the top of the head, starting some distance behind the eyes and working between them to the mouth. Scrape away the flesh and cut carefully through the bony material revealed until you can see the brain. Snip the bony material away carefully until the complete brain is revealed (Fig. 32). Note that the brain consists of a number of pairs of lobes. Each pair has a different duty to perform; for example, the olfactory lobes in the front have to do with smell, and the optic lobes, which you can also see, are connected with sight (Fig. 32). Do not trouble with any other structures until you come to more advanced work.

**Nutrition.** From an examination of the contents of the stomach it seems that many fish are omnivorous, that is they can eat almost anything. However, various fish, such as the herring, have their favourite food supply. The herring lives on small shellfish floating on the surface of the sea. These tiny shellfish move south as the seasons change, and the shoals of herring follow them.

**Reproduction.** There are male and female fish. The male fish produces sperms and the female, eggs. When the female is ready to lay her eggs she chooses a suitable place; for example, the salmon lays her eggs on the gravelly bottom of a stream. The male follows her closely and as soon as she has laid her eggs he comes forward and covers them with a fluid containing numerous minute sperms. This fluid is called milt. Eggs and sperms unite, and the formation of very many tiny fish is the result.

## The Bird

The lovely song-birds of our land, and even the cheeky sparrows, are among our favourite wild animals. Their habits have been studied closely, and we know a great deal about them, much more than there is space to tell here.

**Migration.** You know that certain birds, such as the swallow, migrate or go south to spend the winter. Many reasons have been given for this habit of migration, but it is probably not yet fully understood. It seems easy to find a reason for moving south in the winter when the food supply in the northern land has been exhausted, but why trouble to come north again in the spring? It has been suggested that birds come north to nest and rear their young because of the long days of the northern summer. The young require so much food that the parents have to work hard all the hours of daylight. I once noticed a blackbird who had a nest near our house. In May he was up at three o'clock and, after singing his morning song, was busily employed collecting grubs until, at eleven o'clock in the evening, I heard him singing his good-night song.

**Observation.** It is certainly unkind to keep wild birds caged in the laboratory. Tame birds, such as canaries, may be kept if you wish to study their habits at close quarters. It is much more profitable to spend as much time as one can with field-glasses and camera, observing the habits of wild birds in various parts of the country.

**External Features.** The head is provided with a strong beak (Fig. 33) upon which are two nostrils, two eyes, each having three eyelids, and two ears just behind the eyes. As the eyes are set at the side of the head, it is difficult for the bird to see in front. You must often have noticed a thrush looking down sideways at the earth as if he were listening.

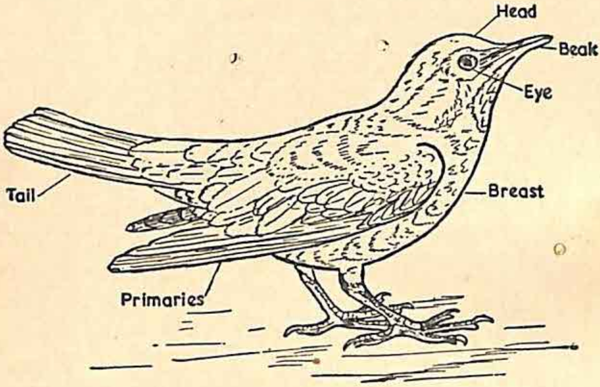


FIG. 33. The Bird.

The third eyelid of the bird moves across the eye and not up and down. You can see a remnant of this eyelid in your own eye if you look at the inner corner. Apparently our far distant ancestors possessed the eyelid fully developed, but it has now been reduced to a remnant.

The ears have no external portions as ours have, but nevertheless the bird can hear quite well.

The body of the bird tapers towards the tail. On it are found the wings, which take the place of our arms, and the legs, which serve the same purpose as our legs. The legs end in feet, which are usually clawed so that the bird can hop and perch.

The most characteristic feature of the bird is its thick covering of feathers. When the feathers have been plucked from a dead bird the body appears to be very small. The feathers are useful in a number of ways, the three most important are: (1) they keep the bird warm; (2) they shed water readily so that the body is kept dry; (3) they enable it to fly.

Feathers are of three kinds. The large quill feathers (Fig. 34) are found in wing and tail. Each consists of a shaft, and a vane or blade on each side of the shaft. Each vane is made up of a number of barbs, and on each barb are two rows of tiny barbules. One row of barbules points towards the tip of the feather and is provided with a set of small hooks; the other row points towards the base of the feather. On the latter are ridges into which the hooks of the row of barbules below it can fit.

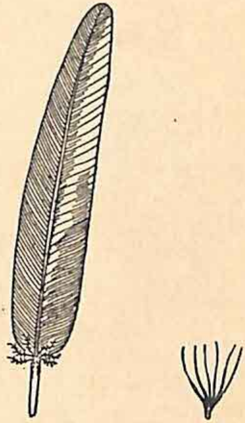


Fig. 34. Different kinds of Feathers.

The covert feathers are much smaller than the quill feathers and are very numerous. They cover the body of the bird and give it its shape. They also keep the bird warm, because they entangle a layer of air around the body. Air, being a bad conductor of heat, prevents the warmth of the body being lost. You must often have seen a sparrow fluffing out its feathers on a cold day. This is to provide a larger layer of air and so a still more efficient barrier to the loss of heat.

Young birds are always covered with very fluffy feathers called *down* (Fig. 34). These come off, and are replaced with covert feathers as the birds get older. Some birds, however, always have down feathers, for example the various kinds of duck. The breast of the eider-duck is thickly covered with down, and she uses this to line her nest.

**Adaptations for Flight.** The body of the bird with its streamline shape, like that of the fish, is well adapted for rapid movement through the air.

The bones of the bird are light, because they have numerous spaces in them which are filled with air.

The large feathers in the wing can be locked together as previously described. This is done when a downstroke of the wing is made, so that the wing offers a strong resistance to the air. In the upstroke the hooks in the wing feathers become disconnected and the air can get through readily. Compare the downstroke of the bird with your own breast-stroke at swimming.

The wings are moved by the strong muscles on each side of the breast. They form the flesh which you like so much when you are eating chicken. The two larger muscles perform the downstroke and the two smaller, the upstroke.

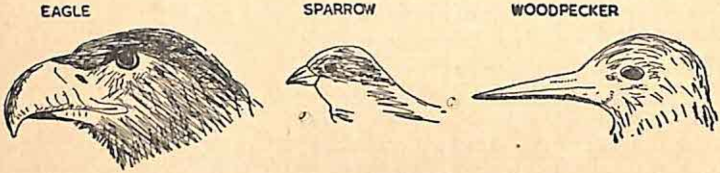


Fig. 35. Adaptation of Beak.

The direction of flight is controlled by the tail, which acts like the rudder of a ship.

**Respiration.** Like the frog the bird breathes by means of lungs, but, in addition, these are prolonged into air-sacs found in almost every part of the body, even in the bones. This renders the supply of air available for respiration much greater; you will see later why this is essential for the bird.

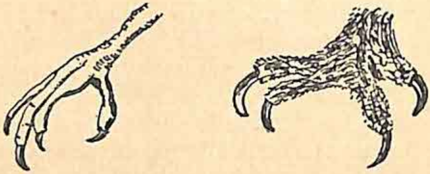


Fig. 36. Adaptation of Feet for seizing and holding (left) and for perching (right).

**Nutrition, and Adaptations for Obtaining Food.** Different birds differ very much in the type of food they prefer. There are the blackbirds and thrushes which rid our gardens of insect pests, the sparrows which pick up crumbs at our feet, the canaries which live on a seed diet, and the birds of prey, like the eagle, which prefer flesh.

Study Fig. 35 carefully and you will see how the beaks of the birds are adapted for obtaining the food they eat; e.g. the seed-eating birds, such as the sparrow, with its small, blunt beak; the woodpecker, with its pointed beak suitable for digging insects out of tree-bark; and the eagle, with its strong hooked beak for tearing flesh.

Look also at Fig. 36, which shows how the feet are modified. Many of the common birds have clawed feet for perching; others, like the eagle, have talons to aid in seizing and holding their prey.

**Reproduction.** Like the butterfly, the male bird places the sperms inside the body of the female and the eggs are fertilised before they are laid. It is when we consider the birds that we find the first signs of parental care; but this will be discussed more fully in a later chapter. You will have watched, I am sure, the care with which the parent birds construct the nest and make it cosy for the youngsters. You will have been struck with the devotion displayed by the parents as they tend and feed their young.

## CHAPTER V

## FOOD OF PLANTS

Sources – Soil – Types of Soil – Salts obtained in Solution from the Soil – Osmosis, Simple Experiments – Carbon Dioxide obtained from the Air – Experiments to show that Carbon' Dioxide is used up and Oxygen given out – Simple Test to show that Starch is present in Green Leaves – Experiments to show what Conditions are Essential for Starch Formation

The mode of nutrition in plants, as you have been told, is very different from that of animals. Plants, because of the presence of the green colouring material, chlorophyll, can manufacture sugars and starches from water, which comes from the soil, and the gas, carbon dioxide, which comes from the air. This process can be carried on only in daylight. When the sugars and starches have been formed they can readily be built up into more complicated substances and finally into protoplasm, the substance of which all living material consists.

The two sources of food supply, therefore, are the soil and the air. We will deal with the soil first.

### Types of Soil

There are many different types of soil, depending on the size of the particles which make up the soil. If the particles are large they form sand, if they are small clay is formed. Usually the soil found in a well-cultivated garden will contain both sizes of particles and, in addition, decaying plant and animal material called *humus*, which gives the soil its rich, dark appearance.

Carry out the following simple experiment. Bring in some soil from your garden. Shake some of it up well in some water in a flask and pour into a tall glass jar. Leave for some time to settle. Make a diagram to show how much sand and clay are present. You will find that plant remains (humus) float on the top of the water because they are least dense, the sand grains are lowest because they are densest, and the clay particles rest upon the sand.

If the soil is very sandy the water will run right through it very rapidly and it will soon become dry. If the soil contains much clay the water will be held for a much longer time; in fact if the soil is very heavy the water will be held so long that it will become sour, and this is not suitable for plant roots. The roots will be choked, since there are few air-spaces, and respiration (see Chapter IX) will be difficult. If lime is added to the soil the particles of clay cling together in groups, leaving air-spaces between, and this renders the soil much more suitable for the plants.

If you dip a small pebble into water and then let it drip you will find that a film of water clings to its surface for some time. Every little grain of sand or clay is like a minute pebble. When the soil is sufficiently moist each little particle has a film of water surrounding it (see Fig. 38). It is this water, only, which the plant can use; any water in the spaces between the particles is merely turning out the air which the plant roots require for respiration, hence the necessity for careful drainage of 'waterlogged' soils.

Since the plant can only make use of the film of water round the soil particles, it is obvious that a large number of small particles will be much better than a small number of large ones. This is why the soil is cultivated to break down the soil particles as much as possible, and this is why the earthworm is so useful to man; it can break down the soil particles much more efficiently than he can himself.

*All plants do not require the same kind of soil.* Potatoes, for example, like a light sandy soil; in fact, good crops of potatoes are often grown by the seashore, in almost pure sand to which a little manure has been added. Roses, on the other hand, prefer a clay soil.

## How the Water Enters the Plant; Osmosis

You will have seen that plants flourish only when the roots obtain an adequate supply of water. You have been told that the water is essential in the formation of sugars and starches, and that it contains simple salts in solution which are necessary for building up the protoplasm of the plant. How does the water containing the salts enter the plant? Carry out the following experiments and they will show you how this takes place.

*Experiment I* (Fig. 37). Soak a parchment tube closed at one end in water for 24 hours. These tubes, called diffusion tubes, can be obtained from any scientific dealer. Choose a rubber, one-holed stopper which tightly fits the open end of the tube. Work the end of a piece of glass tubing, about 2 to 3 feet long, into the hole in the stopper so that it just passes through. Fill the soaked tube about three-quarters full with cane sugar and then fill to the top with water. The experiment works much better if the solution of cane sugar is very strong. Fit the stopper and bind the parchment tube to it tightly with silk-covered wire.

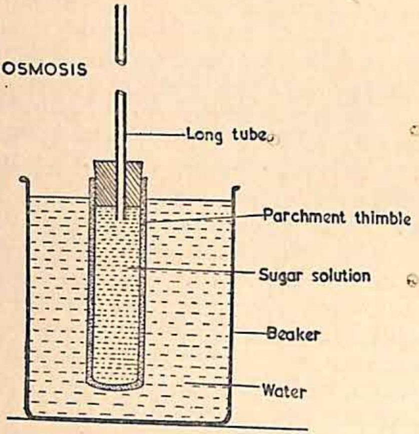


Fig. 37. Apparatus for showing osmosis.

Place the tube in a beaker of water, as shown in the diagram. When the experiment commences the sugar solution should be showing above the stopper in the glass tubing. Mark this level with a thread.

Within an hour, if the experiment is going well, the level of the sugar solution in the glass tube will have risen and, next day, it may be flowing over the top of the tubing.

*Experiment II*. Tie a piece of cellophane paper tightly round the end of a piece of glass tubing $\frac{1}{4}$ inch thick and about 1 foot long, so that it forms a bag. The cellophane paper sometimes wrapped round chocolate boxes will not do as it is usually waterproof. See that there are no cracks in the bag. Make a strong solution of cane sugar and pour it down the glass tube until the liquid appears above the bag. Mark the level with a thread. Place the bag in a beaker of water and leave till the next day.

Note the rise in level of the liquid in the tube and compare it with the rise obtained in Experiment I. Taste the water in the beakers in Experiments I and II. Which is sweeter? Which prevents the sugar coming through more efficiently, parchment or cellophane?

*Experiment III.* Obtain some large raisins and several prunes. Place these in a dish of water and leave till next day. Prunes and raisins have become plump but there is less water in the dish. Where has it gone?

*Experiment IV.* Choose two large potatoes. Cut an end off each so that they will stand easily. Hollow out the potatoes until a wall is left about ½ inch thick all round. Boil one to kill the protoplasm. Place a little sugar in the hollow in each potato. Stand each potato in a dish of water and leave until next day.

The water passes into the living potato but not into the boiled one. Taste the water outside the potato in each dish. The water around the dead potato is sweet because the sugar solution has come through, whilst that around the living potato is not sweet.

What conclusions can we draw from the above experiments? Let us set them out in order.

(1) Water passes through a membrane, such as cellophane, parchment or living potato, to a stronger solution on the other side. Very little of the stronger solution passes out.

(2) The passage of water through a membrane to a stronger solution is termed *osmosis*.

(3) The membrane used must be semi-permeable, i.e. the water must be able to pass in but the substance in solution cannot pass out.

(4) Very little sugar solution, if any, passes out through the cells of the living potato. Living cells can control osmosis. Root hairs can select the amount and nature of the salts admitted and adjust them to the particular requirements of the plant.

Study the enlarged diagram of a root hair (Fig. 38). It consists (1) of a cell wall lined with protoplasm; (2) a nucleus embedded in the protoplasm; (3) a vacuole in the centre of the cell filled with cell sap, a solution containing sugar and other substances.

The cell wall supports the protoplasm, which forms a semi-permeable membrane. Outside, the membrane is a weak solution of salts in the soil. Inside, the cell sap forms a much stronger solution. Therefore, by osmosis, the water in the soil containing the salts can pass into the root hair. It is not quite certain how the salts do enter the root hair, but it is certain that they must be in weak solution before they can do so.

How can osmosis be explained? Present-day biologists find the explanation very difficult and are not quite sure that a satisfactory conclusion has been reached, at least one which can be given simply. The following explanation is easy to follow, but it does not satisfy all the requirements of the advanced student.

Look at the diagram in Fig. 39. You may have heard that solids, liquids and gases are made up of tiny units called molecules but those in liquids and gases are free to move about. Sugar is made up of such molecules, but, though still very tiny, they are much larger than the water molecules in which the sugar may be dissolved. The diagram shows a small piece of a semi-permeable membrane much more highly magnified than the highest powers of the microscope are capable of effecting. The holes in the membrane are large enough to permit the water molecules to pass but too small for the sugar molecules. Water, therefore, passes to the sugar side, but it

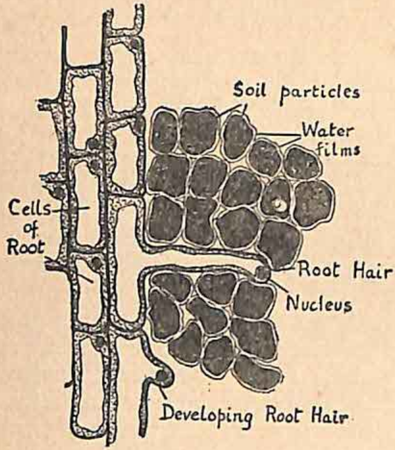


FIG. 38. Diagram of section of Outer Cells of Root, Root Hairs and Soil Particles.

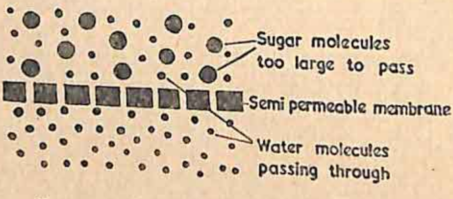

Sugar molecules too large to pass
Semi permeable membrane
Water molecules passing through

FIG. 39. Diagram to explain osmosis.

cannot pass back so readily due to the attraction of the sugar molecules for water.

Semi-permeable membranes are rarely, if ever, perfect; most allow the sugar molecules to escape to a slight extent.

In the plant cell the explanation is still more complicated. The living cell, as stated before, allows certain salts to enter as well as the water, and a little of the cell sap passes out from the cells at the tip of the root to lubricate the root cap and permit it to slip easily through the soil.

## Formation of Starch

The water taken in by osmosis reaches the leaf and there meets the carbon dioxide which has been taken in from the air. These two unite to form sugar and starch in the presence of the green colouring material, chlorophyll, and under the influence of sunlight. Oxygen is given off as a waste product.

*Experiment I. To show that oxygen is given out as a waste product by water plants.*

Set up the apparatus shown in Fig. 40. Place some water plant, such as Canadian Pondweed (*Elodea*), Starwort (*Callitriche*), or Water Milfoil (*Myriophyllum*), under the filter funnel. It is worth trying to obtain various water plants from ponds in your district, as some may give much better results than others; sprigs of mint give satisfactory results if no water plants can be obtained.

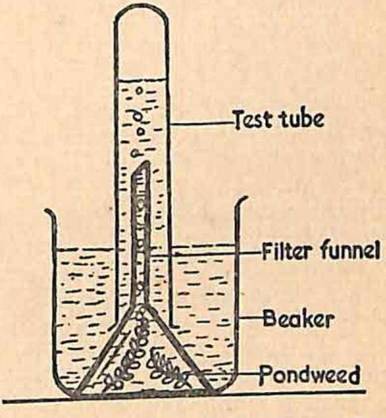


Fig. 40. Apparatus to show that Oxygen is given off from Water Plants.

Fill the test-tube with water and invert it over the narrow end of the filter funnel. Place the apparatus in bright sunlight, if possible, and leave for some time. The experiment works more readily if the water is kept saturated with carbon dioxide by passing the gas through it at frequent intervals.

In bright sunlight a gas is given off abundantly by the water weed. This gas is collected by displacement of the water in the test-tube. When the test-tube is full remove it, and test the gas with a glowing splinter: the splinter should burst into flame, showing that the gas given off is rich in oxygen.

*Experiment II. To show that oxygen is given off as a waste product by land plants.*

Set up the apparatus shown in Fig. 41. Cover the water in the glass trough with a layer of paraffin oil. The oil will prevent carbon dioxide being absorbed by the water. Place two supports of some kind in the trough, and on one place a healthy pot plant, on the other a lighted candle. Cover both with a well-stoppered bell-jar. Place the apparatus in the dark for some time.

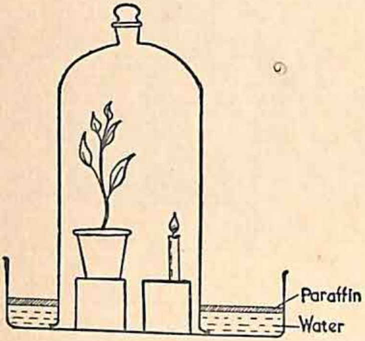


FIG. 41. Apparatus to show that Oxygen is given off from Land Plants.

You will notice that, after a little time, the candle goes out and the water rises in the bell-jar. This is because the oxygen in the bell-jar has been used up by the burning candle and by the respiration of the plant (see Chapter IX), and water has risen to take its place.

Transfer the apparatus to a sunny window and leave for some time. Then remove the stopper from the bell-jar and test the air inside with a glowing splinter. The splinter glows more brightly, and therefore oxygen must be present. Lower a small test-tube of lime-water into the bell-jar. It does not become chalky and, therefore, there is no carbon dioxide present.

*Conclusion.* When the plant grows in sunlight it uses up carbon dioxide and gives out oxygen.

Why is carbon dioxide used up and oxygen given out? To understand this you will have to know a little chemistry. You should know that water contains hydrogen and oxygen, and carbon dioxide contains carbon and oxygen. The carbon in the carbon dioxide joins with the water to form sugar and starch, and the oxygen is set free and can be collected.

The next thing to do is to prove that starch is present in green leaves.

*Experiment III.* Carry out the following test for starch. Get a very little laundry starch powder and shake it up well in a test-tube three-quarters filled with water. Heat until the liquid has become clear. Add a few drops of iodine solution and note the colour. It should be deep blue or almost black. Iodine stains starch blue.

*Experiment IV. To prove that starch is present in leaves grown in sunlight.*

Take some leaves from a plant which has been exposed to light during the day. It is best to perform this experiment in summer and as late in the afternoon as possible. Boil the leaves in water for ten minutes to kill the protoplasm. This allows the chlorophyll to leave the cells more easily. Place the leaves in a beaker containing methylated spirits, and place this beaker in a larger one containing hot water. The chlorophyll dissolves in the methylated spirit, forming a green solution.

As soon as the leaves have been sufficiently bleached remove them to a white dish and pour over them a weak solution of iodine. The leaves go almost black, showing that starch is present.

*Experiment V. To show that the presence of light is necessary for starch manufacture.*

Repeat Experiment IV, using leaves from a plant which has been kept for two days in the dark. No starch will be found present.

*Experiment VI. To show that the presence of chlorophyll is necessary for the manufacture of starch in leaves.*

Choose some variegated leaves; those from a variegated geranium are very suitable. Make a careful sketch of one or two of the leaves, marking clearly those areas which are green, due to the presence of chlorophyll, and those which are colourless. Treat the leaves as described in Experiment IV.

It will be found that the areas which contained chlorophyll stain with iodine; those areas which had no chlorophyll do not stain. The presence of chlorophyll is necessary for the manufacture of starch.

*Experiment VII. To show that the presence of carbon dioxide is necessary for the formation of starch in leaves.*

Put up the apparatus as shown in Fig. 42. Nasturtium seeds take about five to six weeks to germinate and grow. When the seedlings reach a suitable size remove them from the pots in which they have been raised and place in the dish of water. Into the glass tube pour some caustic potash solution, which will absorb all the carbon dioxide present in the air in the tube. Arrange some of the leaves so that they pass through the split cork and rest just above the caustic potash solution. The cork should be dipped in melted wax for some time and then allowed to cool. This prevents air entering the jar through any holes in the cork.

Leave for two days, and then test the leaves from inside and outside the tube, in the afternoon, for starch. No starch is present in the leaves taken from inside the tube, but there is starch present in those leaves which were outside. Carbon dioxide is necessary for starch manufacture in leaves.

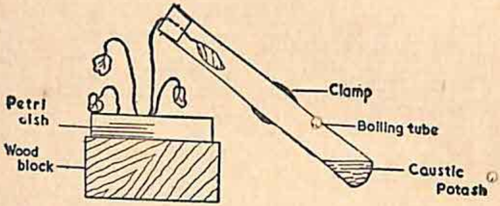


FIG. 42. Apparatus to show Starch Formation.

By the results obtained from the above series of experiments the statement previously made has been proved. This stated that 'in the leaves, water from the soil unites with the carbon dioxide from the air to form sugars and starches, in the presence of chlorophyll and under the influence of sunlight; oxygen is given off as a waste product.'

There has been much discussion by botanists as to whether sugar or starch is first formed in the leaf. The present opinion seems to be that sugar is first formed, but it is immediately transformed into starch, which is stored in the leaf during the day. During the night the starch is again converted into sugar so that it may be transported to any part of the plant which needs it.

From what you have learned it is obvious that plants perform a very important service for all living things. They replace the oxygen which has been used up in respiration. It has been estimated that the amount of oxygen given out by green plants roughly balances the amount of oxygen used up in respiration by all living things. Thus the atmosphere is kept suitable for life.

There is a certain amount of reason to support the idea that plants and flowers, harmless, indeed beneficial, during the day, should be removed from the sick-room at night. Certainly a plant will be adding slightly to the supply of oxygen during the day when it is manufacturing sugar and starch. At night, on the other hand, it is using up oxygen. Actually a single plant, or a solitary bunch of flowers, will make very little difference to the atmosphere of a room. Some people who will carefully remove flowers from their bedroom, will cheerfully take their pet cat or dog to sleep there. The animal will use up much more oxygen than the flowers.

# CHAPTER VI

## FOOD STORES IN PLANTS

COMMON FORMS IN WHICH FOOD MAY BE STORED – TESTS FOR SUGARS, OILS, ETC.– FOOD STORED IN ANY PART OF THE PLANT, SEED, LEAF, STEM AND ROOT – EXAMPLES: BEAN, HYACINTH BULB, CROCUS CORM, POTATO, TURNIP, CARROT, BEET – USES OF FOOD FOR GERMINATION AND GROWTH – EXPERIMENTS TO SHOW THE CONDITIONS NECESSARY FOR GERMINATION AND GROWTH

You have seen how raw materials such as water and carbon dioxide are acquired by the plant and manufactured into sugars and starches in the leaves. You have been told that the food is transported during the night to every part of the plant which requires it. The next thing is to consider how that food is stored during unfavourable conditions, for example during winter, so that it is ready when required more urgently.

Food is stored in a number of different forms. We have already mentioned sugar and starch. When you have some nuts to eat, cut one in half and press the cut surface on to a sheet of white paper. A greasy mark will be left because most nuts contain a large amount of oil. Oil is present as a food store, so that the young plant present in the nut is able to grow when the nut is planted. It will be sufficient, now, if we deal with food stored up by plants in the form of sugar and starch. Later you may learn more of the other forms in which food is stored in plants.

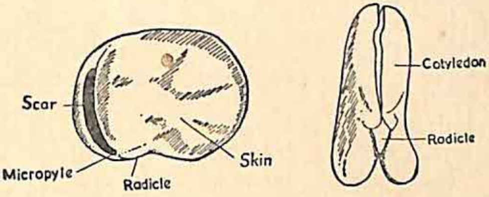
Food can be stored in any part of the plant, root, stem, leaf and seed. Obtain as many of the plants mentioned below as you can, study each one carefully, make named diagrams to show the structure and carry out the tests suggested.

### The Broad Bean

Obtain some large broad beans and make a sketch of one showing the wrinkled coat and the black scar which is clearly visible at one end (Fig. 43). This scar is called the hilum, and was left when the bean was pulled away from the stalk, which attached it to the pod in which it was formed.

Obtain some fresh broad bean pods or some pea pods, which are very similar. You will find that the pod opens easily down each side. Within are seeds attached to the wall of the pod by short stalks. The pod is really a fruit containing seeds. You will learn more about fruits later.

Soak some bean seeds for 24 hours and examine and sketch once more. The bean has become much larger and the skin is smoother, because water has entered. How did the water enter? When you remove and examine the tough skin of the seed you will find that it is almost impossible for water to pass through it. Take one of the soaked beans and squeeze it gently, looking carefully at the scar as you do so. You should be able to see water oozing from a tiny hole at one end of the scar. This hole is called the micropyle, and it is through the micropyle, mainly, that water enters and leaves the seed.



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FIGS. 43–44. The Seed of the Broad Bean.
43. Side view; 44. End view.

Remove the seed coat and note that scar and micropyle come with it. Make another sketch of an end view of what remains (Fig. 44). You will see the young root or radicle and the sheath through which it is beginning to grow.

Most of the seed consists of fleshy material which easily splits into two parts. Each part is called a cotyledon or seed-leaf. Between the two seed-leaves you will find the young root or radicle and the young stem or plumule. The seed is really a tiny plant with root, stem and leaves containing food.

Cut one of the seed-leaves across and place a drop of iodine solution on the cut surface. A deep blue stain will be seen, showing that starch is present. The use of the seed-leaves is to store food for the young plant so that it can grow when conditions are favourable.

## The Hyacinth Bulb

Examine and sketch the external structure of a hyacinth bulb. You will find that the outside is covered with a number of thin, papery, brown leaf-like structures, the tunic leaves. At the base is a flat disc-shaped body. This is the stem, called, because of its shape, a disc stem. Fine roots, called adventitious roots because they arise from a stem and not from another root, grow from this when the bulb is planted.

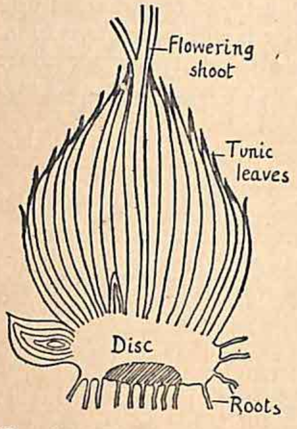


FIG. 45. The Hyacinth Bulb (note the buds growing out of the base).

Cut the bulb carefully down the centre into two equal parts and examine.

(1) In the centre of the bulb is the flower-bud, which will grow out next season to produce leaves and flowers.

(2) Surrounding the flower-bud are white fleshy structures at the bases of which may occasionally be seen tiny buds, which will form new bulbs.

(3) Outside the fleshy structures are the thin papery leaves seen before.

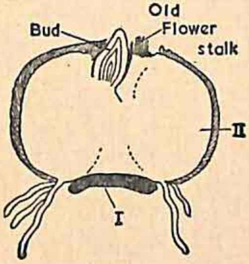
Place a drop of iodine on the cut surface of the fleshy structure and note that a deep blue stain results, showing that starch is stored in it.

Grow some hyacinth bulbs in glass vases filled with water. Keep them until the flowers have been produced and have withered. Cut one in half and note the changes that have taken place (Fig. 45). The flower-bud has grown up, producing flowers and leaves. Roots have grown out from the disc stem. The leaves have withered, but their bases have persisted and have become swollen. The swollen leaf-bases were filled with food which was manufactured in the green part of the leaf during the summer and passed down to them for storage. Some of the outer leaf-bases have been exhausted of their food supply and now form the thin scaly covering of the bulb.

## The Crocus Corm

The crocus corm is sometimes spoken of as a bulb, but this is not correct, as you will find after examination. The corm is very different from the bulb of the hyacinth.

Examine and sketch a crocus corm. You will find that it has a thin, scaly, brown covering of leaves. At the top are the remains of the old flower stem and the bud which will grow out to produce the flower of the next season. Underneath the corm of the present year (II) are the remains of the corm of the previous year (I) (Fig. 46). A bud has been formed in the axil of a scale leaf towards the top of the corm; in the axils of the leaves lower down, buds, which will probably not develop further, may be seen.



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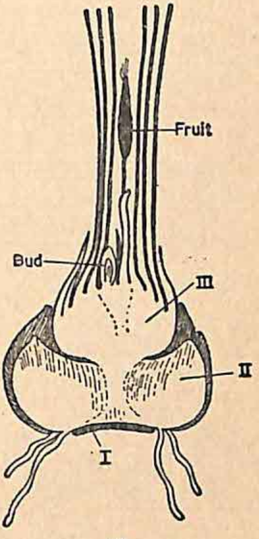

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FIGS. 46–47. The Crocus.
46. The corm; 47. The plant after flowering.

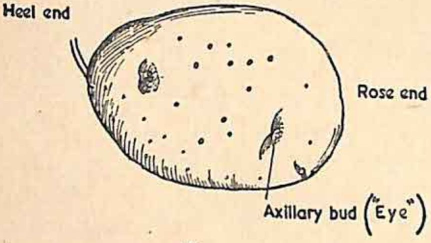
Remove the scaly leaves and examine the fleshy structure disclosed. On it you can see a number of circular scars showing where the scaly leaves were attached. The white structure must therefore be a stem, and the name, corm, is given to it.

Cut the corm into two and you will see that it is formed of solid, white, fleshy material. Place a drop of iodine solution on the cut surface and a dark blue stain is produced. Food is stored in the corm in the form of starch.

Plant some crocus corms in cocoanut fibre or in soil and allow them to develop until the flowers and leaves have withered. Examine carefully and sketch (Fig. 47). The food in the old corm (II) has been used up; and the bud which you saw when you examined the corm, having given rise to a flower and leaves, has now produced a new corm (III). The leaves during the summer produced starch, and this was passed to the base of the stem and was stored; thus a new corm was formed.

## The Potato Tuber

Wash the soil from a potato and examine and sketch it (Fig. 48). You will notice that there are a number of 'eyes' scattered over the tuber, especially at one end, which is called the 'rose end.' The eyes are buds which will grow out to form new shoots when the potato is planted. Round each eye is the so-called 'eyebrow.' This is really a small ill-developed leaf. At the opposite end of the potato, which is usually called the 'heel end,' is a small piece of the underground stem or a scar, showing the place where the potato was attached to the parent plant.



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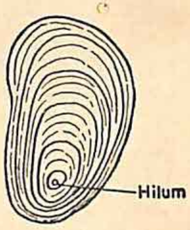

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FIGS. 48–49. The Potato. 48. The tuber; 49. A starch grain (*enlarged*).

The presence of buds and leaves on the potato shows that it must be part of a stem, but no green chlorophyll is present because the stem has grown underground. The potato tuber is the swollen end of an underground stem.

Scrape a little of the flesh of the potato on to a microscope slide, add a drop of water and examine carefully under the microscope. You will find a number of grains shaped rather like tiny oysters (Fig. 49). The hilum is the centre from which the starch grain began to develop. Add a drop of iodine solution to the preparation of starch grains on the slide and examine once more under the microscope. They are stained deep blue. Food is stored in the potato tuber in the form of starch.

### The Turnip

Wash, examine and sketch a small turnip (Fig. 50). Note that there are no buds present, but you may see a number of fibrous roots. The turnip is not a stem but a root.

Cut the turnip across and touch the cut surface with iodine solution. The iodine does not stain the flesh of the turnip dark blue but remains brown. No starch is present. You must now learn how to test for sugar.

*Test for Sugar*. Obtain some of the special kind of sugar known as glucose. Dissolve the glucose in warm water. Your teacher will have two special solutions prepared called Fehling's Solution No. 1 and Fehling's Solution No. 2. Add a little of each of these to some of the glucose solution in a test-tube. Boil the mixture and a brick-red precipitate will rapidly form.

Repeat the above test, using some small pieces of turnip instead of the glucose. The same brick-red precipitate is obtained, showing that food is stored in the turnip in the form of glucose sugar.

### The Beetroot

Wash, examine and sketch a small beetroot (Fig. 51). Note that there are two lines of fibrous roots, one down each side. The beetroot is a true root.

The red colour of the beetroot renders it difficult to test for starch, unless a sugar beet, which is yellow in colour, can be obtained. By examination under the microscope, however, and staining with iodine solution, it can be established that there is no starch present, even in a red beet.

The test for glucose gives no result with the beetroot. Another test must be carried out which is a modification of the test for glucose.

*Test for Cane Sugar*. Dissolve a little cane sugar, the ordinary sugar which you use in your tea, in water in a test-tube. Test this solution with the two Fehling's solutions as you did with the glucose solution. No red precipitate is obtained.

Pour a little more cane sugar solution into another test-tube. Add a few drops of hydrochloric acid to it and heat gently (do not allow to boil). Cool by running cold water over the test-tube. Test with litmus-paper and you will find that the solution is acid. Add a little caustic soda solution until a neutral reaction is obtained. Now test with Fehling's solution again. This time a red precipitate is obtained. The cane sugar is a complex sugar and it has to be broken up into two simpler sugars, one of which is glucose, before the test with Fehling's solution will work.

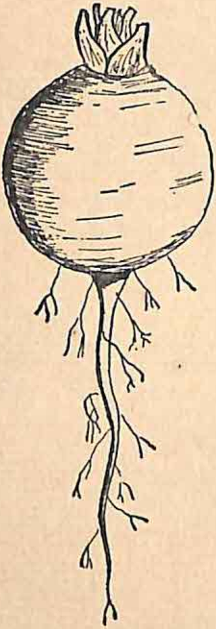


FIG. 50. The Turnip.

FIG. 51. The Beetroot.

Cut up some beetroot into very small pieces and put a few of these into a test-tube. Add a little water and a few drops of hydrochloric acid and repeat the test for cane sugar. A red precipitate is formed, showing that food is stored in the beetroot in the form of cane sugar.

## Germination and Growth

What are the uses of these food-stuffs manufactured by the plant?

(1) They are used to liberate stored energy in the form of heat, or in the form of the energy required to perform actions necessary for the existence of the individual.

(2) They are essential for the continuation of germination and for growth. Every seed is provided with a store of food to enable the young plant within to continue growth until it is able to obtain food for itself.

*Conditions for Germination.* When the seed is placed in suitable conditions it commences to grow. This is known as germination. Carry out the following experiments and you will discover the conditions necessary for germination.

*Experiment I.* Obtain two flat glass dishes with closely fitting lids. Those known as Petri dishes, after the scientist who first used them, are very suitable. Cut out several pieces of flannel to fit the bottom of each dish. If the flannel is thick, one layer in the bottom of each dish is sufficient; if it is thin, two layers should be used.

Soak the flannel in one dish but leave the other dry. In each dish sow some mustard seeds and leave them for two or three days.

The mustard seeds in the dish with the damp flannel germinate but those on the dry flannel do not. Moisture is necessary for germination.

*Experiment II.* Put up two dishes as described in the previous experiment but soak the flannel in both cases. Place the one dish in the light and the other in the dark.

In two or three days the seeds in both dishes have germinated. Light is not necessary for germination.

Watch the seedlings for a few more days. Note that those in the light are sturdy and the leaves are green. The seedlings kept in the dark are lanky and the leaves are pale yellow. Light is necessary for healthy growth.

*Experiment III.* Cover the bottom of one Petri dish with fresh water, and the bottom of two more dishes with water which has been boiled for 15 minutes to drive out the air. Sow some mustard seeds in each dish. Cover the surface of the boiled water in one of the dishes with a layer of olive-oil to exclude air. Leave for a few days and note the results carefully.

The seeds in the fresh water will germinate readily, those in the boiled water without olive-oil will probably germinate but it will take much longer for them to do so, whilst those in the boiled water with olive-oil will not germinate at all.

Wash the seeds in the olive-oil dish carefully and place in a dish containing fresh water. In a day or two they will germinate, showing that the olive-oil has not killed them.

The seeds germinated readily in the dish with fresh water because there was air present in the water which they could use for respiration (see Chapter IX). They did not germinate so readily in the boiled water because the air had been driven out from it and had gradually to be absorbed again from the atmosphere. They did not germinate in the water covered by the olive-oil because air could not pass through the layer of oil. Air is essential for germination.

*Experiment IV*. Prepare and fill three small flower-pots with well-moistened soil. Sow some mustard seeds on the soil in each pot. Place one pot near the radiator, one inside the window and the other outside the window. This experiment is most successful if the weather is cold and the pot is put outside a window facing the north. Leave for a few days.

The seeds near the radiator germinate most rapidly, provided that care is taken to see that they do not dry up. Those inside the window germinate next. Those outside the window may not germinate at all, depending on the temperature at the time. The conditions in this experiment vary so much that careful records should be kept as the results may vary considerably.

The results will probably show that seeds require a certain temperature for germination.

*The three essential conditions for germination are moisture, air and heat.*

**Growth.** The conditions essential for germination are also essential for the continued growth of the plant. In addition, light and an adequate food supply are necessary for healthy growth.

*Experiment V*. Plant some broad beans, which have been soaked for 24 hours, in pots of soil. Follow the growth, digging them up at first to investigate the development underground. Make sketches at frequent intervals (Fig. 52).

Note that the root grows out first and obtains a supply of moisture from the soil. This is soon followed by the growth of the shoot. At first the shoot grows up through the soil with the tip curved to protect the tender growing point. As soon as the shoot has pierced the soil the tip straightens. During the early stages the root grew much more rapidly than the shoot, but later on the shoot begins to catch up with the root and soon surpasses it in the rapidity with which it grows. The first pair of green leaves soon opens, and the young plant commences to manufacture food for itself. The seed-leaves remain below ground, and provide the growing plant with a supply of food until its own food manufacture is satisfactorily established and it has become independent of the store of food in the seed.

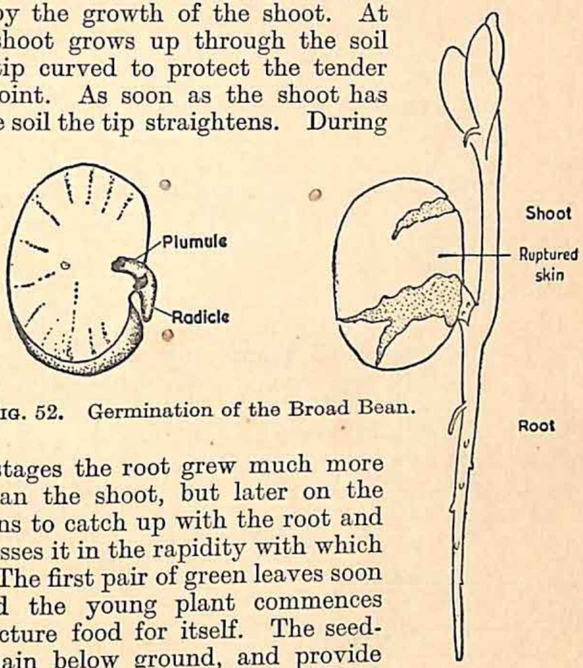


FIG. 52. Germination of the Broad Bean.

The bean plants can be grown and tended until flowers are produced.

Grow some beans in sand to compare with those grown in soil. Sand does not contain much food material and the plants will not flourish nearly so well.

It will be better to consider the more complicated question of the food supply of animals later when some of the simple animals have been examined.

# CHAPTER VII

## TRANSPIRATION IN PLANTS

MEANING OF TRANSPIRATION – SIMPLE EXPERIMENTS TO SHOW THAT TRANSPIRATION TAKES PLACE THROUGH PORES ON THE SURFACE OF A LEAF – EXAMINATION OF THE PORES UNDER THE MICROSCOPE – TRANSPIRATION CURRENT – EXPERIMENT TO DETERMINE THE RATE OF THE TRANSPIRATION CURRENT – CONDITIONS INFLUENCING TRANSPIRATION AND THE TRANSPIRATION CURRENT – USES OF TRANSPIRATION TO THE PLANT – ROOT PRESSURE

You have already learned that the plant takes in a great deal more water than it requires because the salts necessary for the building up of the plant body can only enter in weak solution. We are now going to investigate the manner in which this water leaves the plant.

You must often have watched the pools on the street dry up when the sun comes out after a shower. How does the water disappear? The heat of the sun causes the liquid water to be transformed into water vapour which is invisible and, being less dense, rises into the atmosphere. This process is called *evaporation*.

Much the same process takes place in the plant. The water enters the plant and passes through it into the leaves as a liquid. As it reaches the surface of the leaf it is transformed into water vapour, and passes out through tiny pores on the under surface of the leaf. This process is not quite the same as evaporation. The opening and closing of the pores is controlled by the plant, and this regulates the rate at which the water leaves the leaf. This process is given another name,

### Transpiration

*Experiment I. To show that transpiration takes place from the leaf of a plant.*

Procure a vigorously growing plant, a geranium plant will serve, and water it well. On the following day take a circular piece of rubber sheet, large enough to cover and overlap the pot. Make a cut from the edge to the centre of the sheet, place the rubber sheet over the top of the pot so that the stem of the plant comes through its centre, seal the slit from the centre to the margin with surgical adhesive plaster. Tie the overlapping rubber sheet tightly round the top of the pot as shown in Fig. 53. Weigh the plant and pot and record the weight. Place a bell-jar over the plant and leave it in sunlight.

The sides of the bell-jar soon become clouded on the inside with minute drops of water, which must have come off from the leaves since pot and soil are covered with waterproof material.

Remove the bell-jar and leave the plant in the sun for an hour or two longer. Weigh again. The weight is less because water has been lost from the leaves.

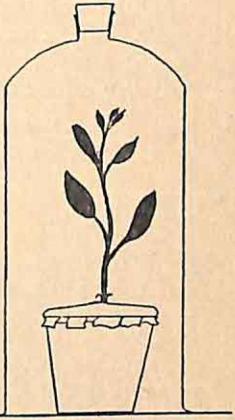


FIG. 53. Apparatus to show Transpiration.

*Experiment II. To show that the leaves cannot transpire water vapour if the pores are blocked.*

Repeat the above experiment, but choose a plant with few leaves and carefully cover the lower surface of the leaves with a thin layer of vaseline. Very little water vapour will be given out, so the sides of the bell-jar should remain comparatively dry and the plant will not lose water.

*Experiment III. To examine the pores on the under surface of the leaf.*

Procure a fresh leek with several green leaves and keep it in water overnight. The leaves will then be quite crisp. Next morning choose a good stiff leaf, bend it over your finger and make a small shallow nick on the lower surface. Tear away the leaf tissue until you get a part that is so thin that it is quite transparent. Cut off a little of the transparent tissue and mount it in water on a microscope slide under a cover-slip. Your teacher will show you how to do this.

This transparent tissue is the skin of the leaf. Examine under both low and high powers of the microscope. Make careful drawings in each case (Fig. 54). You will find that the tissue is made up of a number of spaces divided from each other by walls. These were called *cells* by the early biologists because they resemble the cells of the honeycomb. Some of the cells are long and narrow and are quite colourless. Others are short and sausage-shaped, and appear to have much denser contents than the long cells. The sausage-shaped cells are arranged in pairs, each pair surrounding a mouth-like opening. The mouth-like openings are the pores through which the water vapour escapes from the plant.

Make up a solution of salt in water, 5 gm. of salt to 100 c.c. of water. Place a drop of the salt solution at one side of the cover-slip and hold a piece of blotting-paper or filter-paper directly opposite at the other side of the cover-slip. This will draw out the water at one side, and the salt solution will enter from the other side to take its place. Watch the pores carefully under the high power of the microscope and note that they gradually close. By osmosis the weaker cell sap solution is passing out of the cells surrounding the pore; these collapse and the pore closes. Wash the little piece of skin in water and mount on the slide once more. On examination you will find that the pores have again opened.

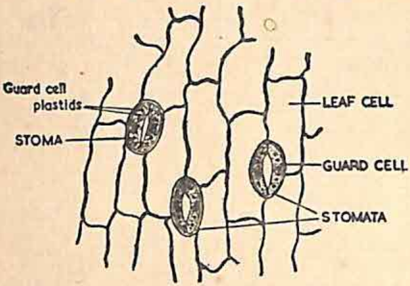


Fig. 54. Skin of Leaf in surface view showing Pores.

Since the cells surrounding the pore seem to protect it and are important in opening and closing it, they are called guard cells. The pore itself is called a *stoma*. Stoma is the Greek for 'mouth.'

### The Transpiration Current

As the water passes out from the leaves in the form of water vapour more water must pass up through the plant to take its place. This causes the formation of a current called the transpiration current.

*Experiment IV. To measure the rate of the transpiration current.*

Set up the apparatus shown in the diagram (Fig. 55). Care must be taken that the apparatus is entirely filled with water. Get fresh twigs or stems of any plant with large leaves. I have found by experience that cherry-laurel or some broadleaved evergreen generally works very well, but the selection of the plant used is a matter for individual experiment. The twig should be cut under water so that no air enters at the cut surface, and the stem should fit tightly into the hole in the first rubber stopper. A tube, with a graduated scale attached to it, is passed through the second rubber stopper.

Introduce a bubble of air by lifting the end of the glass tube out of the vessel of coloured water for a minute or two. A piece of filter-paper held to the tip of the tube will hasten matters. Replace the tube in the water, and the bubble should soon commence to travel towards the plant, showing that water is being absorbed and passed out through the leaves. The experiment is most successful in direct sunlight.

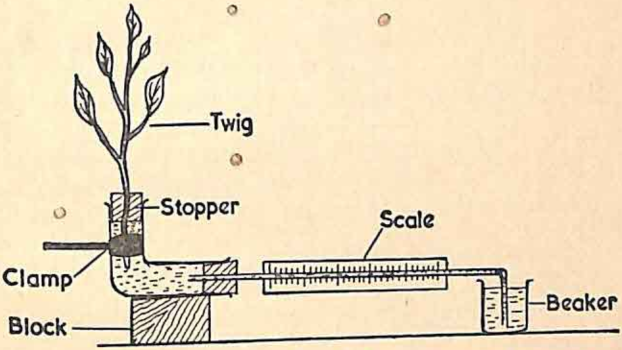


FIG. 55. Apparatus for showing Transpiration Current.

When the bubble has reached the graduated scale note the time it takes to travel four or five inches; from this the rate per hour of the transpiration current can be calculated, and hence the rate at which the leaves are transpiring.

**Conditions Influencing the Rate of Transpiration.** Repeat Experiment IV, placing the apparatus (i) in a shaded part of the room; (ii) in a greenhouse or under a glass cover within which the air can be kept very moist; (iii) on a chair between an open door and window so that a current of air is blowing over it.

From the above experiments it will be found that—

(1) Transpiration is most rapid in sunlight.
(2) Transpiration is decreased in a damp atmosphere.
(3) Transpiration is increased when a wind is present to dry the atmosphere.

## Uses of Transpiration to the Plant

(1) Transpiration enables the plant to get rid of some of the water absorbed by the roots.

(2) Transpiration is responsible for the formation of the transpiration current by means of which, to a large extent, water and dissolved salts can travel from the root to the leaves.

(3) Transpiration lowers the temperature of a plant, and thus prevents it becoming over-heated on a very hot day.

## Root Pressure

Transpiration is not the only force which aids in raising the water in a plant. The following simple experiment will show that another force, called root pressure, is also responsible.

*Experiment V*. Choose an actively growing plant, such as a geranium. Water it well in the evening and next morning cut off the top, leaving a stump one or two inches above the ground.

It will soon be noticed that drops of water ooze from the cut surface of the stump. The water is pumped out of the plant by root pressure. This is a force which pushes the water up the stem. How it functions is rather difficult to understand, and requires a deeper knowledge of the structure of the plant than it is the purpose of this volume to give.

The pushing force of root pressure and the pulling force of transpiration are sufficient to account for the raising of a column of water up to 70 feet high. Many trees are taller than this, and scientists find it difficult to explain how a column of water sufficiently high for them has been raised. A recent suggestion is that the column of water just grew up with the tree; it never had to be raised to that height. It does not take nearly so much force to maintain the column of water at 100 feet as it would to raise it to that height.

## CHAPTER VIII

## SOME SIMPLE PLANTS AND ANIMALS

STRUCTURE OF A TYPICAL PLANT AND ANIMAL CELL – STRUCTURE OF PLEUROCOCCUS – SPIROGYRA – MUCOR – MOSS – FERN – AMŒBA – HYDRA – SIMPLE EVOLUTION – DARWIN'S THEORIES OF EVOLUTION

Before studying more fully nutrition in animals and reproduction in plants and animals, it will probably make things clearer if you know a little about some of the simpler plants and animals.

Many people who have not studied Biology are of the opinion that there are very few plants beyond the flowers and trees with which they are familiar, and few animals worth consideration once dogs, rabbits, cows, sheep, lions, tigers, and a few others have been disposed of. This is far from being the case. In the plant world, for instance, flowering plants form a very small part of the whole. There is a vast world of plants outside this group, many of which are much simpler in structure and mode of life. Study of simpler plants and animals has thrown much light upon the life processes in more complicated plants and animals.

### The Plant and Animal Cells

Before investigating the structure of some simple plants and animals it is necessary to know something of the structure of a typical plant and animal cell.

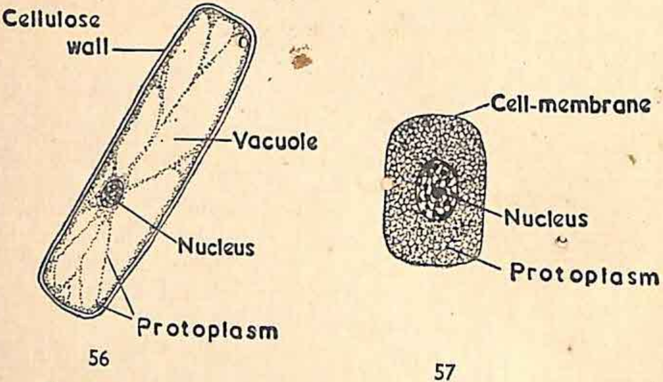
In Fig. 56 is shown a plant cell such as you may obtain in tomato pulp, the flesh of apple, or privet berry. Mount a little of any of these on a microscope slide in a drop of water. Add a little dilute iodine to some of your preparations, as this may bring out the structure more clearly. Examine the cells under the highest magnification of your microscope.

The cell has a firm wall, generally made up of a substance known as cellulose. This wall aids the cell to keep its shape and protects the contents within.

Inside the wall is a mass of foamy or granular material called *protoplasm.* This is the living substance of which all plant and animal structures are built. The protoplasm can build a cell wall when necessary.

Throughout the protoplasm can be seen what appear to be empty spaces, so they are called *vacuoles.* They are really filled with cell sap, which contains sugar and other food materials in solution.

At one point in the protoplasm can be seen a denser, rounded structure which can be stained brown with iodine.



Figs. 56–57. Structure of Cell. 56. Plant; 57. Animal (*both enlarged*).

This is the *nucleus.* It is the directing force of the cell and controls all the life processes, such as food manufacture, reproduction, etc. It is the essential part of the cell. A cell can live without a cell wall and much of its protoplasm, but it cannot live without a nucleus.

In the protoplasm surrounding the nucleus are a number of small bodies called *plastids.* These are very important in various ways. They may be coloured brightly and so render flowers attractive. In cells present in the leaves or young stems of the plant they may be coloured green because of the presence of the important green material, *chlorophyll,* which has an important part to play in the manufacture of food for the plant. They are then called *chloroplasts.* They are present in the guard cell (Fig. 54).

The typical animal cell (Fig. 57) is much like the plant cell. With a clean scalpel scrape a little tissue from inside your cheek. Mount this in a little water and examine under the microscope. Stain with iodine to show the nucleus.

The animal cell, like the plant cell, consists of foamy protoplasm, but there are no large vacuoles and there is no definite cell wall, only a limiting layer of somewhat denser protoplasm. There are no green chloroplasts or other bodies to give colour to the cell or to take part in the manufacture of food. The nucleus is very similar to that present in the plant cell. This gives a picture of a typical animal cell, but not all animal cells are the same; they are modified for so many purposes.

Now we can proceed to the examination of some simple plants and animals.

## Pleurococcus

You must often have seen the bright green powder on old damp walls or on the bark of trees. This powder is usually more common on the north side of a tree, and it is possible to find the way through a forest by observing this fact.

The green powder is made up of an immense number of individuals of a tiny green plant called Pleurococcus. It is a relative of the large brown seaweeds that you find by the shore when you are on holiday.

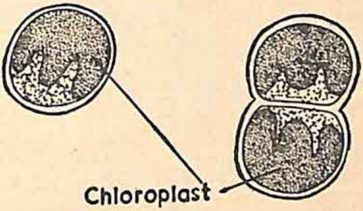


FIG. 58. Cells of *Pleurococcus* (*enlarged*).

Each individual is very minute and must be examined under high powers of the microscope (Fig. 58). Examine under the low power first and you will see that the plants are small and spherical in shape and green in colour. They are often attached to each other in groups, an explanation of which will be given later.

Turn on the high power and try to make out as much of the structure as you can. The tiny plant has a fairly thick wall. The most conspicuous content is a large green chloroplast which covers most of the inner surface of the cell wall. The nucleus cannot be seen because it is hidden by the chloroplast. Scientists have been able to discover it only by cutting sections through the cell, a very difficult thing to do.

You will see that the cell of Pleurococcus is just a typical plant cell. The individual is one of the simplest plants known, for it consists of one single cell. This cell is able to carry out every function of the plant—feeding, growing, breathing, division to form new plants, etc. The two cells formed by division often remain in contact and, after several divisions, groups are formed.

## Spirogyra

Spirogyra is a relative of Pleurococcus, and therefore allied to the seaweeds. It does not live by the sea, but in fresh-water ponds and slow-flowing streams. It forms a bright green slimy mass on the surface of the water. Bring some of the bright green mass into the laboratory and keep it in a glass dish.

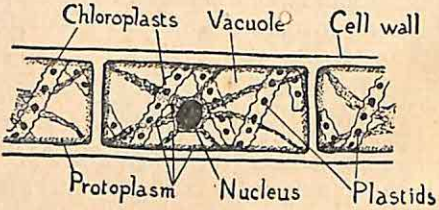


FIG. 59. Part of Thread of *Spirogyra* (*enlarged*).

Take a very little Spirogyra and place it on a microscope slide in a drop of water. With a pair of dissecting needles pull the green mass apart as much as possible. Put a glass cover-slip over it and examine under the low powers of the microscope (Fig. 59). You will find that the mass is made up of a number of fine green threads. Each thread is formed of barrel-shaped cells joined end to end. Round the inner surface of the cell wall a green chloroplast is wound spirally, hence the name Spirogyra.

Examine a few threads stained with iodine under the high powers of the microscope. On the green chloroplast you will see dark spots which are due to the presence of starch grains stained dark blue by the iodine. Examine these in an unstained preparation and you will be able to distinguish them as bright dots. These are concerned with starch manufacture.

The nucleus is stained dark brown with the iodine solution. It is suspended in the centre of the cell surrounded by a layer of protoplasm, which is joined by strands of protoplasm to another layer lining the inner surface of the cell wall.

Spirogyra is a little more complicated in structure than Pleurococcus. It does not consist of a single cell but of threads formed by a number of cells. Each cell, however, is complete in itself and can carry out all the life processes.

### Mucor

Mucor is a very different plant from the two just described. It can be readily cultivated in the following simple way. Take a small piece of white bread—brown bread does not seem to be so successful—damp it thoroughly, but do not make it too wet, as this will encourage the growth of bacteria instead of Mucor. Wipe the damp bread on the classroom floor and place it in a Petri dish, or cover it up in some way, so that the moisture will not evaporate too quickly.

In a day or two the damp piece of bread should be covered with a growth of white cottony threads on which small black dots can be seen; these threads are called hyphæ (*sing.* hypha). This is the plant Mucor, and, as you have seen, it is not green in colour as were the two plants previously examined. This means that chlorophyll is lacking and, therefore, Mucor cannot manufacture sugars and starches for itself; it must depend on other plants for its food supply. It grows on the food material in the bread which has been provided by the wheat plant.

Mucor belongs to a group of plants closely allied to the seaweeds, called the *Fungi* (*sing.* fungus). All the members of this group are devoid of chlorophyll, and so are dependent upon other plants or animals for their food supply. You will probably be familiar with the common *mushroom*, another fungus which is found growing in pastures where horses have been grazing, making use of the horse-dung as its source of food.

Take a few threads of Mucor off the bread and transfer them to a microscope slide. Examine them under the low power of the microscope and you will be able to make out some of the dark heads and the threads upon which they are growing (Fig. 60); mount a few more threads in a drop of water on another slide and examine again under low power. You will be able to make out the threads more clearly, but the little black heads have burst, and out of them have come many much smaller bodies, each of which consists of a single cell and is called a spore. These are the bodies which will grow into fresh Mucor plants. They are so light that they float about in the air very readily, and are nearly always present in the dust on the floor of a room. That is why you were told to wipe the bread on the floor of the classroom.

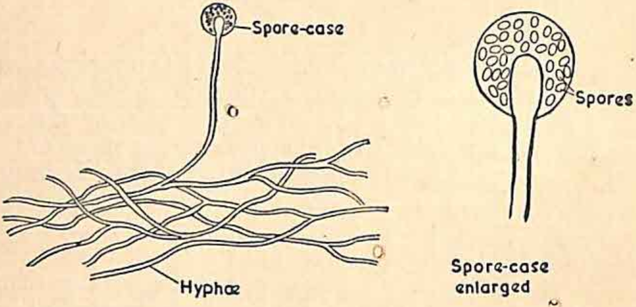


FIG. 60. *Mucor*. Threads and spore-case.

The little spores are much simpler than seeds. The seed, as you know, contains a young plant with a store of food, but a spore is only a single cell. Each spore, when it reaches a suitable position, can soon grow out to form a thread.

## The Moss

There are a large number of beautiful mosses which live in many different kinds of homes, but most of them agree in their love for moisture. You may find them growing on old damp walls or on the damp soil under forest trees. One moss (*Funaria hygrometrica*) grows very luxuriantly on ground which a fire has passed over. Unfortunately, the beautiful mosses have attracted comparatively little popular attention, and very few have been given everyday names like the wild flowers.

Let us study a typical moss like that shown in Fig. 61. Look for some of these, particularly in the autumn, and you will probably be able to make out the small 'fruit-bodies.'

The moss plant consists of stem, leaves and root-like structures. These root-like structures are much simpler than the true roots of higher plants. They are called *rhizoids*, and are formed of cells which are specially adapted to obtain water and dissolved salts from the soil like the root hairs of higher plants. Look at a rhizoid under the microscope and you will see that it is made up of simple cells which are all alike.

Remove a leaf from the moss and examine it under the microscope. It is made up of a number of cells, one layer thick except at the midrib. Each cell contains a number of green granules which are the chloroplasts.

Each oval fruit body rises from a slender stalk from the midst of a cluster of leaves, and consists of a capsule containing a large number of tiny spores which, when sown in suitable conditions, grow and give rise to new moss plants.

You will see, from the above description, that the moss is a great advance on Spirogyra. It is built up of cells, but these cells are specialised for special purposes: the rhizoid cells for water absorption, the leaf cells for food manufacture, some of the stem cells for transport of water, and the cells of the fruit body for the production of spores.

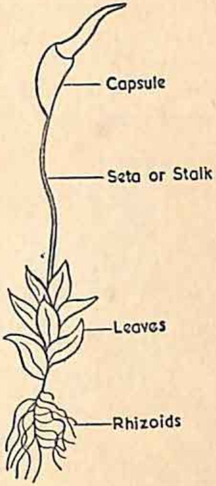


FIG. 61. The Moss.

## The Fern

Look for ferns when you go for a walk through a wood or along the bank of a stream. Bring in some fern leaves, often called fronds, to examine in the laboratory. Outside you should watch the fern develop from early spring right through the summer. Two common ferns which you will find easily are the *Male Shield Fern* and the *Bracken*. The Male Shield Fern grows in woods and may be seen in many gardens. The Bracken is found chiefly on the hillsides, and is a perfect nuisance to farmers as it spoils the ground for sheep. The best treatment to get rid of it is to cut it down three times during the growing season, but this is a costly business.

Watch the leaves of the Shield Fern as they grow up from the soil. Note how, at first, they are coiled at the tip like a bishop's crozier. They soon spread out and form the big handsome leaf which is the most conspicuous part of the plant. The leaf is divided up into a very large number of tiny leaflets.

Dig up a fern plant carefully and examine the short thick stem which lives all its life underground. From the foot of the stem arise a number of roots. These are true roots and not the rhizoids found in the moss. Root and stem are quite complicated in structure and show a great advance on the rhizoid and stem of the moss.

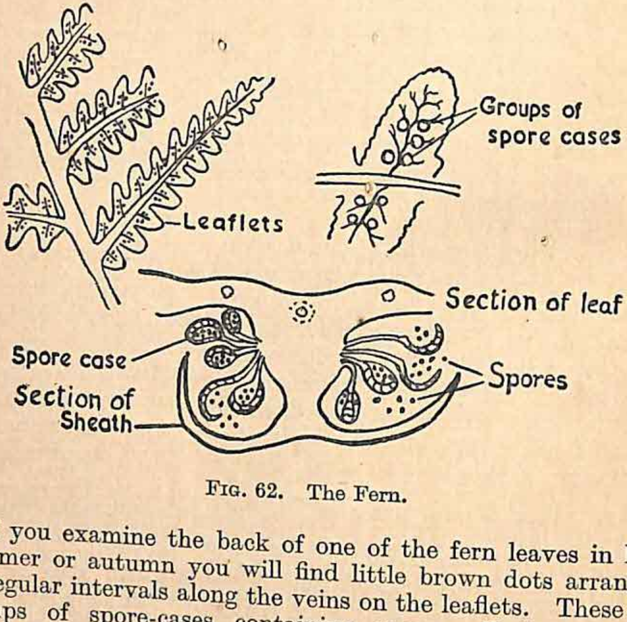


FIG. 62. The Fern.

If you examine the back of one of the fern leaves in late summer or autumn you will find little brown dots arranged at regular intervals along the veins on the leaflets. These are groups of spore-cases containing spores. Each group is covered with a shield-shaped, transparent sheath, hence the name of the fern. Each spore body contains a number of tiny spores. Spores and spore-cases can only be seen under the microscope (Fig. 62).

The fern is much more complicated than the moss. The moss has only leaves and stems, but no true roots; the fern has true roots, stems and leaves.

It is only a step now to the seed-bearing plants with which you are much more familiar.

You will see from the above that plants fall naturally into groups: (i) the very simple plants, such as Pleurococcus and Spirogyra; (ii) the more complicated spore-producing plants, such as the fern and moss; (iii) the still more complicated seed-producing plants.

### Amœba

Let us now turn to the study of some simple animals, and, as in the plant world, you will find that the simplest are single-celled.

Bring in some muddy pond-water and examine it under the microscope. You may find small jelly-like specks present in it. These are usually small and difficult to distinguish, but much bigger specimens may be obtained from various scientific firms. These little specks are individual animals, each called Amœba.

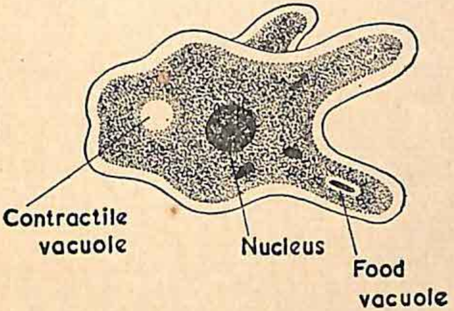


FIG. 63. Amœba (*enlarged*).

Place one or two of the animals on a slide in a drop of water and examine under the low powers of the microscope (Fig. 63). Note that the amœba consists of a single cell with a clear layer of protoplasm forming a limiting layer rather than a distinct skin or wall. Within the clear layer the protoplasm is dark and granular. There will probably be a number of vacuoles present in which food particles can be clearly seen. These are called food vacuoles.

Watch a large amœba carefully and you may be able to see it moving gradually forward. It puts out a finger of clear protoplasm and into this the granular protoplasm flows;

thus the creature moves forward. This form of movement is so characteristic of amœba that it is known as *amœboid movement.* The power of movement is used in the capture of food. Amœba puts out one or two projections of clear protoplasm which flow round and engulf any food particles, such as the bacteria present in the water.

Turn on the high power of the microscope and watch the granular protoplasm carefully. It flows in one direction for some time and then reverses and flows in the opposite direction. Time it carefully and you will find that it flows for a longer period in the direction in which the animal is moving. You may be able to see that one of the vacuoles is free from food particles and appears and disappears rhythmically. This is the contractile vacuole through which excess water and soluble waste products are expelled. The solid, undigested food material is left behind as the animal flows forward.

Stain an amœba cell with iodine solution or, better still, obtain a stained preparation from a scientific dealer. In this you will be able to make out the deeply staining nucleus and to observe the absence of chloroplasts.

Amœba, the single-celled animal, differs from Pleurococcus, the single-celled plant, in the following ways:

(1) The wall of the cell is not so definite.

(2) There is no green chloroplast present, hence the food problem requires that the cell shall have power of locomotion to go in search of the food supply which it is unable to manufacture for itself.

(3) A contractile vacuole is present. In the animal the expulsion of waste products, liquid and solid, becomes important.

### Hydra

The little animal, Hydra (Fig. 64), may be found attached to water weeds, stones, etc. in ponds, damp ditches and in streams, or it may turn up unexpectedly in one of the aquaria. If there is difficulty in obtaining it, scientific dealers will probably be able to supply specimens. Put any hydra you may have to spare into one of your small aquaria and they will probably establish themselves there and commence to reproduce.

There are two common kinds of Hydra, one brown and the other green. The colour is not due to the animal itself, but to tiny one-celled plants, one green and the other brown, which have found a home in the cells of the animal.

Hydra is just visible to the unaided eye, so only low powers of the microscope are required for its examination. Detach a hydra from the stone or side of the aquarium upon which it is growing, and place it in a small watch-glass containing water for examination under the microscope.

Hydra is a small tube-shaped animal with the tube closed at one end. Throughout it is made up of small cells attached to each other like bricks. The wall of the tube is formed of a double row of these cells. The open end of the tube forms a mouth, which is surrounded by a number of waving tentacles. The tentacles apparently resemble the many heads of the monster, Hydra, which Hercules had to kill, hence the name given to the animal.

Try to obtain some live water-fleas (*Daphnia*) from a pond in the neighbourhood. They will grow and multiply readily in a small aquarium, and can be made out as little white specks darting to and fro in the water. Place two or three water-fleas in the water with the Hydra and watch under the microscope. You may be able to see a waving tentacle catch a water-flea and push it into the tube of the Hydra, which acts as a stomach, and digests it. On the tentacles are certain cells which possess stings and paralyse the water-flea, then it is easy for the tentacle to push it into the stomach.

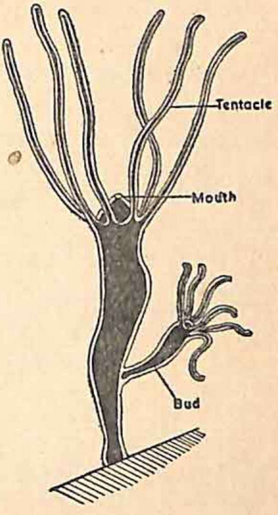


FIG. 64. Hydra (*enlarged*).

It is a big jump from Amœba to Hydra. Amœba is one-celled, and the single cell can feed, respire, grow and reproduce. Hydra is made up of many cells, and these are adapted for special purposes. The stinging cells aid in catching the food. There are cells in the wall which act like our muscles and cause the animal to lengthen or contract as required. Other cells in the wall are sensitive, and send a message up to the muscular cells telling them when to lengthen or contract. Still other cells on the inner side of the wall give out a fluid which helps to digest the food (Fig. 65).

There are many animals which come between Amœba and Hydra on the ladder of development, but they will have to be left until you go further with the subject.

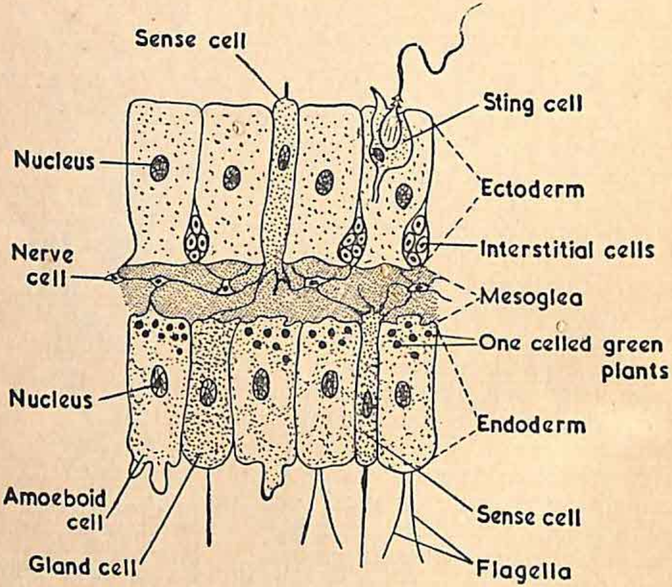


FIG. 65. Hydra. Structure of section of the wall (*much enlarged*).

It is not a far cry from Hydra to the earthworm, then come the butterfly and moth, and so on to the fish, frog and rabbit.

Animals can be divided into two great groups:

(1) Those like Amœba, Hydra, earthworm and butterfly which have no backbone, called the *Invertebrates*.
(2) Those like the fish, frog, bird, rabbit and man himself which have a backbone, called the *Vertebrates*.

## Evolution

The way in which so many different kinds of plants and animals have arisen has always been one of the greatest of wonders. One of the earliest explanations was given by those who interpreted the first chapter of Genesis absolutely literally. God created all living things, plant and animal, in a very short period of time, and since then no new animals or plants have appeared.

Now the professional gardener and the breeder of animals know that the above is not a complete explanation. The gardener has discovered how to produce varieties of plants which are more beautiful and more useful than their wild ancestors. The breeder of animals can improve the various breeds and render them more useful from his point of view. It is impossible to describe here how this wonderful work is carried out. It often takes years of patient experiment before any marked improvement in plant or animal is obtained, but success is generally attained in the end. In the years since man has commenced to cultivate plants and animals he has made such improvements that it is often difficult to recognise the ancestor with which he started. For example, the modern potato is much bigger and finer than those Sir Walter Raleigh brought back from America over three hundred years ago.

How did so many different kinds of plants and animals arise? You have seen how the simplest plants and animals are single-celled, and how more complex forms arise as we pass up the ladder of development. This process of development from the simple to the more complex is called Evolution, and there are many proofs that this process accounts for the varied plant and animal life present in the world to-day.

One of the most striking proofs is given by the science, Geology, which deals with the story of the rocks. Geologists are able to prove that many of the rocks which build up our land have taken millions of years to form. During this time plants and animals have lived and died and their remains, or casts of their forms, have been embedded in the rocks, thus being preserved. Such remains are called *fossils*. These show that the simplest plant and animal remains are found in the oldest rocks and the most complex forms in the newest rocks, thus proving conclusively that the development has been from the simple to the more complex.

There are other proofs that evolution has taken place, but they will be understood more readily when the subject is studied more deeply than is possible in the present course.

It is to the great scientist, Darwin, that we owe the first clear explanation of evolution and how it works. Darwin voyaged round the world in a ship called the *Beagle*, and examined plants and animals in many countries. From his observations he came to the conclusion that he could actually see the process of evolution going on under his very eyes. He tried to find some explanation of how the process worked, and he came to the following conclusions.

Plants and animals which are strongest and best suited to survive, persist and give rise to offspring more or less like themselves, and some of which will inherit the characteristics which made it possible for their parents to survive more readily. It may happen that some of the offspring inherit a favourable character more strongly than their parents, and are still more adapted for life in the environment in which they are placed. These in their turn will transmit their good characters to their offspring, and so a race will arise well adapted for life in the surrounding environment, but differing markedly from the ancestor from which the race sprang. If the conditions of the environment change or the species move to fresh surroundings, the process of adaptation commences once more. Darwin called his theory 'the survival of the fittest.' His conclusions may be summed up briefly. New species of plants and animals have arisen through the process of evolution which works in the following way. The plant or animal is a bundle of characters, some favourable, others not so. Environment encourages the development of favourable characters and suppresses others; those plants and animals most suited to their environment survive, the others perish. Darwin's theories have been modified in the light of later research, but they still form the basis of our scientific knowledge on this subject.

It is not so generally known that another Englishman, named Wallace, published his theories of evolution at the same time as Darwin. Though the two worked quite separately they came to very similar conclusions. The name of Wallace is associated with an imaginary line which he drew separating Australia and the islands immediately north of it from the mainland of Asia. He found that many animals south of this line were very different from those found to the north of it. These belong to a lowly class of the *Mammals*, the group to which man belongs. This lowly class is called the *Marsupials*, because the mother carries her baby in a pocket in her skin until it is able to fend for itself. This is a much lower form than the higher classes of mammals found in Asia. Wallace said that the marsupials had persisted in Australasia because that continent had been cut off from Asia very early, before the mammals had developed the higher types, and so the marsupials had not to face the competition of the higher classes.

Many scientists have investigated the interesting subject of evolution since the days of Darwin and Wallace. As stated previously, all their work has gone to establish the fact that evolution actually has taken place and is at work to-day, and they have added much to our knowledge of how the process actually goes on. The further scientists progress with their investigations the more they are struck with the truth and beauty of the first chapter of Genesis. The order of creation there laid down agrees remarkably with the known facts about evolution.

# CHAPTER IX

# RESPIRATION

WHAT RESPIRATION REALLY IS – EXPERIMENTS TO SHOW THAT OXYGEN IS USED AND THAT CARBON DIOXIDE IS GIVEN OUT AS A WASTE PRODUCT DURING THE RESPIRATION OF PLANTS AND ANIMALS – USES OF RESPIRATION – VARIOUS WAYS IN WHICH PLANTS AND ANIMALS CARRY OUT RESPIRATION

## What is Respiration?

Very often the answer given by students to the above question is that respiration is 'breathing,' or that it is the 'taking in of oxygen and the giving out of carbon dioxide.' Neither answer is correct.

By 'breathing' is usually meant the action carried out by the animal resulting in the intake of fresh air into the lungs and the expulsion of stale air from the lungs. This is a very small part of the whole process of respiration. The action of breathing is visible to the eye; respiration in a plant, for example, can take place without any visible action.

The second answer goes a little further but by no means far enough.

In the first place it is not oxygen alone but air containing, amongst other things, a good proportion of oxygen and a very little carbon dioxide which is taken in. Likewise it is not carbon dioxide which is given out but air containing more carbon dioxide and less oxygen. The air taken in by a human being contains roughly 80 per cent. nitrogen, 20 per cent. oxygen and ·04 per cent. carbon dioxide. The air given out contains the 80 per cent. of nitrogen unchanged but only 16 per cent. oxygen, whilst the carbon dioxide present has risen to 4 per cent.

In the second place the intake of fresh air is only the introduction to the most important part of the process of respiration and the expulsion of stale air is only the conclusion; it is the part of the process which lies between that is most important.

Why does the plant or animal take in the air containing oxygen? The following experiments, which you may already have performed during your Physics course, will provide an answer to this question.

*Experiment I.* Burn a little magnesium ribbon, and note that the bright metallic lustre disappears and the magnesium is changed into a white powder.

Place a little magnesium ribbon in a crucible with a lid. Heat strongly and the magnesium will commence to burn. Note that the magnesium soon ceases to burn unless the lid is raised frequently.

Why does the magnesium cease to burn? It is because the limited supply of oxygen in the crucible is very soon used up, as it combines with the magnesium to form the white powder, oxide of magnesium. Weigh the crucible containing the magnesium before and after burning. It will be found that weight has been gained, a proof that the magnesium has united with the oxygen and so becomes heavier.

*Experiment II.* Heat a glass plate until all the moisture has been driven off. Place a little yellow phosphorus in a crucible and place the crucible on the dry glass plate. Set fire to the phosphorus by touching with a heated glass rod and cover immediately with a bell-jar.

Dense white fumes are formed which settle on the glass plate as a white powder, oxide of phosphorus.

*Experiment III.* Attach a candle to the glass plate by melting a little of the wax at the bottom of the candle. Light the candle and cover with the bell-jar.

The candle will burn for some time, but will then commence to flicker, and will finally go out unless the bell-jar is raised and a fresh supply of air is admitted.

Remove the bell-jar, place a small vessel containing limewater beside the candle, light the candle once more and replace the bell-jar. When the candle has gone out remove the bell-jar and examine the limewater. This has become chalky because of the absorption of the gas carbon dioxide.

The candle contains a great deal of the element carbon, which, on combustion, unites with the oxygen present to form carbon dioxide. Carbon dioxide is an invisible gas, so cannot be seen as were the oxides of magnesium and phosphorus.

All the above experiments provide examples of the process of burning or combustion. As a result of this process oxygen is used up and an oxide of the element is formed.

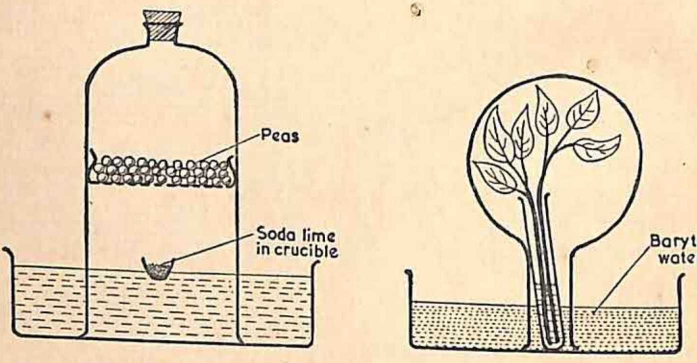
The same process, though at a much slower rate, is going on inside each one of us. Within each one a process of slow combustion is maintained without which life would be impossible, for it produces the heat required for all living processes.

The most important part of the process of respiration is the combination of the oxygen with the carbon present in the food-stuffs taken in by plant or animal. This results in the establishment of a process of slow combustion, and carbon dioxide is formed as a result.

### To show that Plants and Animals Respire

*Experiment I. To show that plants use up oxygen.*

The apparatus is set up as shown in Fig. 66. Some soaked peas are placed on the wire-gauze tray. A crucible containing soda-lime to absorb any carbon dioxide present is floated on the surface of the water in the glass dish. The bell-jar containing the soaked peas is placed over the crucible and tightly stoppered. Care must be taken that the levels of water inside and outside the glass bell-jar are the same.



66

67

Figs. 66–67. Apparatus for showing Respiration in Plants.

One or two days after setting up the experiment it will be seen that the water in the bell-jar has risen about one-fifth of the way up it. On testing the remaining air with a lighted taper the latter goes out, showing that the oxygen present has been used up.

This experiment proves that germinating peas respire, using up the oxygen.

*Experiment II. To show that green plants, on respiration, use up oxygen and form carbon dioxide.*

The apparatus used is shown in Fig. 67. Some fresh green leaves are placed in the test-tube with their stems dipping in water. The glass dish is filled with limewater, or baryta-water, which is more sensitive to carbon dioxide. The level of the baryta-water in the neck of the flask must be carefully noted and marked. The apparatus must be kept in the dark to prevent food manufacture and the accompanying release of oxygen.

After 24 hours the baryta-water will probably have risen about 2 inches up the neck of the flask because oxygen has been used up. A white precipitate will be formed in the baryta-water because of the presence of carbon dioxide.

The above experiment proves that oxygen is used up and carbon dioxide given out when green plants respire.

*Experiment III.* Experiment I may be repeated, substituting a dish containing a little water in which one or two worms have been placed for the soaked peas. Very little water must be used in the dish, only sufficient to keep the skin of the worm moist; a worm will drown if immersed in water.

The results obtained should be more striking than in the case of plants, as the animal respires more actively, as a rule, than does the plant. The reason for this will be made clear later.

*Experiment IV. To show that animals, on respiration, use up oxygen and give out carbon dioxide.*

Experiment II may also be repeated, substituting worms for the green leaves in the test-tube and using very little water.

Since the worms will not carry out food manufacture like the green leaves it is not necessary to keep the apparatus in the dark during this experiment.

## Uses of Respiration

The experiments described above prove that in the case of both plants and animals respiration takes place. The next step is to inquire into the uses of this process, and the following experiment will suggest one of these uses.

*Experiment V. To show that heat is given off by germinating peas.*

Obtain two thermos flasks. They should be as nearly alike as possible. Soak a fairly large number of peas for 24 hours, divide them into two equal parts, and boil one part for about 10 minutes to kill them.

Place the boiled peas in one flask and the unboiled peas in the other. Close each flask with a well-fitting one-holed rubber stopper. Fit each stopper with a thermometer.

Note the temperatures in each flask at the beginning of the experiment. It should be the same in each case.

Leave the flasks for 24 hours and read the temperatures again. You will probably find that the temperature in the flask containing the living peas is 2 to 4 degrees higher than in that containing the dead peas.

Since, owing to the structure of the flasks, no heat can enter, the rise in temperature must be due to the respiration of the living peas. Respiration causes a rise in temperature.

The use of respiration, therefore, is to produce the supply of heat which the plant or animal requires for life. The amount of heat required varies considerably, being greatest in the case of warm-blooded animals like ourselves and the still more warm-blooded bird.

The heat produced is readily transformed into the energy required to carry out all the life processes which are so important for the plant and animal. Without this energy the plant or animal could not respire, grow, absorb food or reproduce.

## How Plants Respire

Wherever the plant is young and tender air can enter over the entire surface. When, however, the skin of the plant is made stronger by a deposit of waterproof material, which happens very soon in its development, air can no longer pass through. The pores or stomata described in Chapter VII are now very important. Air enters readily through them, and the stale air can pass out equally readily.

The air taken in through the stomata dissolves in the water present in the air-spaces in the leaf and passes into the cells of the plant. There the carbon dioxide is used for food manufacture, and the oxygen for slow combustion of food-stuffs to produce the heat which may be transformed into the energy which the plant requires.

### How Animals Respire

You have already been told something about this interesting subject in earlier chapters. Let us now collect this information and add to it when necessary.

**Amœba.** This little creature is surrounded by water throughout its entire life, so its respiration problem is not a very serious one. It makes use of the oxygen dissolved in the water around it. This passes into the cell over its entire surface, the oxygen is used in respiration and waste carbon dioxide passes out, again over the entire surface.

**The Earthworm.** The worm does not live surrounded by water but it does live in moist soil, and it dies if its skin is not kept damp. Oxygen is dissolved in the moisture on the skin and passed into the blood-stream, so that it may be carried to every part of the body and enable respiration to take place.

The earthworm shows an advance on Amœba in the possession of a blood system by means of which the oxygen may be transported to every part of the body. The structure and functions of this wonderful system will be more fully discussed in considering the respiration of man.

**The Insect.** In insects, such as the bee, butterfly, etc. the method of respiration is most unusual. Down each side of the body are found a number of tiny holes which lead into tubes filled with air. These tubes pass throughout the body, taking the air containing oxygen to every part which requires it. There is no need for the blood to take any part in the transference of the oxygen from place to place.

How the insect gets rid of the used air containing carbon dioxide is still rather a mystery to scientists.

**The Fish.** The fish, as you have already been told, respires by means of gills which are richly supplied with blood-vessels. Water enters the mouth and is drawn over the gills (Fig. 30). There oxygen dissolved in the water is taken into the blood-stream and waste carbon dioxide is given out by the blood. The oxygen is then carried throughout the body to every part which requires it.

The fish is provided with a heart which is simpler in structure than that in the frog and man (Fig. 31). This acts as a pump, driving the blood with its supply of oxygen throughout the body.

**The Frog.** Respiration in the frog is exceedingly interesting, as during its life it uses a number of different ways.

The egg is surrounded by water, and so the dissolved oxygen present can pass through the outer surface to the developing tadpole within and provide it with the amount required to keep life going.

When the young tadpole has hatched out it soon develops external gills. These are very delicate structures with the blood very near the surface. If you have a chance you should examine a tadpole at this stage (Fig. 13) under the microscope. Place one in a small watch-glass in a drop of water and examine a branch of an external gill under the low power. You will be able to see the blood-stream flowing quite easily.

Later, the adult tadpole respires by means of internal gills which are quite similar to those in the fish.

The frog has lungs which resemble those of the human being and respires in a similar way. This type of respiration will be considered further in Chapter XIII.

In addition the frog is able to respire through its skin, which must be kept moist like that of the earthworm. During hibernation, when the frog does not need much oxygen, it obtains sufficient through its skin and only respires in that way.

There is much more to investigate in this wonderful process of respiration, for example the intricate system used by the bird; but this must be left until you pursue your studies further in later years.

Respiration in man is so complex and important that it merits a special chapter for itself.

## CHAPTER X

## FOOD OF ANIMALS

HOW THE FOOD PROBLEM OF ANIMALS DIFFERS FROM THAT OF PLANTS – WHAT FOOD-STUFFS ANIMALS REQUIRE – HOW THESE FOOD-STUFFS ARE RENDERED SUITABLE FOR USE; SIMPLE ALIMENTARY CANAL – WHAT USE ARE THE FOOD-STUFFS?

### How the Food Problem of Animals differs from that of Plants

You have already been told that the typical green plant, because it possesses chlorophyll, is able to manufacture complicated food-stuffs, such as sugars and starches, from water and carbon dioxide. The plant can go still further. It can make use of the sugars and starches with the simple salts which have been taken from the soil, to build up the still more complex substances, *the proteins*. The proteins are the most important constituents of the most complex substance of all, *the protoplasm*, which builds up the bodies of plants and animals.

Now the typical animal does not possess chlorophyll, therefore it cannot elaborate complex food-stuffs from the simple substances present in soil and air. It must rely on plants or other animals for its food supply. In the end, of course, all animals must rely on plants for food, whether the animal eats the plant itself or other animals which have fed upon plants. For example, man eats sheep which have fed on grass. The old saying from the Bible, 'All flesh is grass,' is most certainly true.

As animals depend upon other plants and animals for their food supply they are faced with two problems.

In the first place, the animal generally has to move from place to place in search of food. The plant is surrounded by an ample supply of food material in soil and air, a supply which is practically inexhaustible. The animal has the power of locomotion which the plant does not require. The cow moves from place to place in search of fresh grass as she browses in the peaceful meadow. The hawk and eagle swoop down upon their prey with the great speed made possible by their powerful wings.

The second problem which the animal has to face is that of digesting the food it has obtained. The plant makes use of the readily absorbed soluble salts from the soil and the carbon dioxide in the air, and it is only when the insoluble starches have been formed that provision must be made for transforming them into soluble sugars for transport from one part to another.

The animal has two problems in connection with digestion.

(1) The complex food-stuffs taken in must be broken down into a simpler form which can be made use of by the animal. For example, the sugar found in beetroot is more complicated than that found in turnip, and is transformed during digestion into a simpler sugar similar to that present in turnip.

(2) The animal takes in much of its food in the solid form, and this must be broken down and converted into a soluble form before it can pass into the blood-stream and so pass to every part of the body which requires it.

The breaking down of the more complicated food-stuffs and the conversion of the solid material to a soluble form is carried out by the process of digestion. To carry out this process of digestion a digestive system has been developed, very simple in the simpler animals but becoming more complex as one passes up in the animal kingdom. Later in this chapter we will consider some of the ways in which food is obtained and digested by various animals.

## The Food-stuffs Required

The food taken in by animals has three main purposes: (1) it is used in forming the protoplasm which builds up the body tissue and replaces worn-out tissue; (2) it aids in producing the heat which may be transformed to energy and stored for use during the life processes of the animal; (3) it provides the animal with certain substances which aid in protecting it against disease.

Therefore there are three main classes of food-stuffs: (1) the building foods, largely *proteins*; (2) the energy producing foods, *sugars*, starches and fats; (3) the protective substances, the *vitamins*. All plants and animals contain these food-stuffs and so can form a source of them.

Animals differ very much in the sources from which they derive their food supply. Some, like the cow, are *herbivorous*, that is they eat plants only. Others, like the lion and tiger, are *carnivorous*, that is they live entirely on the flesh of other animals. Man is an example of an *omnivorous* animal, he eats both plants and animals.

### How the Food Supply is obtained and rendered suitable for Use by various Animals

We will now consider how several of the animals you have dealt with obtain and digest their food.

**Amœba.** As stated in Chapter VIII, amœba makes use of its power of movement to capture its prey (Fig. 63). In the diagram several stages in this interesting process are shown. The little animal puts out a finger-like process of protoplasm which flows round any germs (bacteria) or other food particles which may be encountered. Thus the food is enclosed in a food vacuole. Digestive juices are poured into the vacuole and the bodies of the bacteria are broken up, the soluble portions being absorbed into the protoplasm through the wall of the vacuole whilst the undigested material is left behind as the amœba flows on.

**Hydra.** As you were told in Chapter VIII, hydra lives on water-fleas which it captures by means of stinging cells on its waving tentacles. These stinging cells are very small, but you may be able to make them out under the high power of the microscope (Fig. 65).

The fluid secreted by the cells paralyses the water-flea and renders it an easy prey. The tentacles push it into the interior of the tube-like body of the hydra, which acts as a simple stomach. The cells lining the inner wall of the tube pour out digestive juices which dissolve the soft inner parts of the water-flea. The hard outer parts are got rid of through the mouth.

In addition to the above method of digestion certain cells, amœboid cells, on the inner wall can actually act like amœba. They put out a finger of protoplasm which flows round the food particles, encloses them in a food vacuole, and there they are digested.

The process of nutrition is a little more complicated in hydra than in amœba. There is a special provision for capturing the food supply, and there is the presence of a simple type of stomach.

**The Earthworm.** The earthworm lives on dead and decaying leaves, which it obtains lying on the surface of the soil or in the earth, which it eats as it makes its burrows.

Now the earthworm has another problem to face. It takes in the decayed leaves in pieces much larger than are the microscopic bacteria and water-fleas which form the diet of amœba and hydra. These pieces must be broken up into much smaller fragments. The smaller the fragments the more readily can the process of digestion proceed, hence the importance of chewing food well.

The digestive system of the worm is adapted for the purpose of grinding down the food taken in as well as digesting it. The dried leaves are taken in by the mouth, which does not possess teeth, and passed into the throat where it is mixed with digestive juices. Down the throat it passes into the gullet, and this in turn leads into a crop or swelling at the base of the gullet. From the crop the food passes into the gizzard. This structure has strong muscular walls, and it grinds the food into fine particles so that the digestive juices can act upon it readily and break it down into soluble substances.

The digested food now passes into the intestine, a long, tube-like portion of the food canal leading from the gizzard to the anus, which is a small hole communicating with the exterior at the opposite end of the food canal from the mouth. As it passes down the intestine, the soluble digested food is absorbed through the walls and enters the blood-stream, in which it is carried throughout the body of the worm. The undigested food passes out with the soil in the intestine through the anus.

**Other Animals.** The digestive system of the earthworm is a great advance on that of hydra, and it is a forerunner of the more complicated structures found in the fish, the frog, the bird, and man himself.

The main portions of such a digestive system are:

(1) *The mouth*, provided with teeth in the fish, frog and man, but without teeth in the earthworm and bird. In the frog and the fish the teeth are of more use in aiding the capture of prey than in breaking up the food when it is obtained. The frog lives on insects caught by flicking out its tongue, and these are 'bolted,' being passed right into the stomach without previous digestion.

Certain species of fish, for example the herring, live on minute living organisms floating on the surface of the sea.

These are so small that they do not require to be ground up. The teeth in the mouth are used to prevent the escape of the tiny creatures when once obtained.

There are some fish, such as the dogfish, which do use their teeth for breaking down their food, but these are more voracious than the herring and capture larger prey.

In most animals, such as dog, cat and man, which possess teeth, these are used for chewing up the food and rendering it suitable for digestion. In the bird as well as in the earthworm the grinding process is carried out by the gizzard.

(2) *The throat and gullet* lead down into

(3) *The stomach*, in which much of the process of digestion is carried out.

(4) *The small intestine* is next to the stomach. In it the process of digestion is completed and the process of absorption is carried out. During absorption the digested food material passes through the wall of the intestine into the blood-stream and is carried to every part of the body which requires it.

(5) *The large intestine* follows the small intestine. In it neither digestion nor absorption of food-stuffs takes place to any extent. Water only is absorbed from the undigested food remaining, so that the latter leaves the body by the anus in a more solid form. In the rabbit small pellets are formed. The waste material which leaves the body is called fæces.

Throughout its passage through the first part of the lengthy food canal the food material is being mixed with digestive juices poured out by a number of glands. The uses and functions of these juices will be considered further when we study the digestion of man in a subsequent chapter.

## The Uses of the Food-stuffs absorbed

As previously stated the food-stuffs absorbed fall into a number of different classes, each class of food-stuffs having its special use.

(1) *The building food-stuffs*, largely proteins, as their name implies, are used to build up the protoplasm which forms the tissues of the body. Thus they are important in growth and in the replacement of worn-out tissue.

(2) *The energy-producing food-stuffs*, sugars, starches and fats, which are readily broken up in combustion and combined with oxygen to produce the store of energy which the animal

needs for its life processes. The fats especially produce heat readily.

(3) *The protective food-stuffs*, vitamins, which are taken in by the animal in several of the foods it eats. Their main purpose is to render the animal resistant against disease. More will be said about these mysterious substances when considering the digestion of man.

(4) *Water and dissolved salts.* The animal needs a large amount of water to keep its cells firm. The amount required differs much with the different animals. The salts dissolved in the water are also important, particularly for back-boned animals. The calcium and phosphorus salts, for example, have much to do with bone formation.

# CHAPTER XI

# REPRODUCTION IN PLANTS

MEANING OF REPRODUCTION – REPRODUCTION IN SOME SIMPLE PLANTS – PLEUROCOCCUS – SPIROGYRA – REPRODUCTION IN THE FLOWERING PLANT – VEGETATIVE REPRODUCTION – REPRODUCTION BY FUSION – POLLINATION – FERTILISATION – RESULT OF FERTILISATION: THE FRUIT, THE SEED

## Meaning of Reproduction

As we have seen, by reproduction is meant the power which the plant possesses to produce new individuals like itself. In most plants there is a specially adapted structure set aside for the purpose of reproduction. In the flowering plant, which is the most familiar type to most of us, this special structure is, of course, called the flower.

In some of the simplest plants which we considered in an earlier chapter the method of reproduction is very much simpler than that found in the flowering plant.

## Reproduction in some Simple Plants

**Pleurococcus.** As described in Chapter VIII, Pleurococcus is an individual consisting of a single, minute, spherical plant cell. The method of reproduction is extremely simple. Each cell can divide into two, and the two daughter cells form new individuals capable of independent existence. The daughter cells can again divide, and so can their daughters. Quite often packets consisting of four or eight cells are found which are made up of individuals formed by the division of a single cell in the beginning. The daughters, granddaughters, and sometimes the great-granddaughters have not separated but have remained attached together (Fig. 58).

The reproduction of Pleurococcus is one of the simplest forms known. It is often known as 'reproduction by simple fission.'

**Spirogyra.** In Chapter VIII the structure of Spirogyra was described. You were told that it was made up of green filaments, each filament consisting of barrel-shaped cells attached end to end. Now these filaments can reproduce in two ways:

(1) *The Vegetative Method.* This method is very simple. The fine threads or filaments break up into small pieces each of which is capable of growing into a mature Spirogyra thread. This method is usually adopted when the plant is able to obtain ample supplies of food and so can flourish abundantly.

(2) *The Fusion Method.* If possible the material used for the observation of the second type of reproduction should be obtained from a place where the conditions for growth are not favourable. The best specimens showing the process of fusion that the author has found came from a slow-flowing stream high up on the Pentland Hills near Edinburgh, where the plant must have been frozen during part of the winter at least.

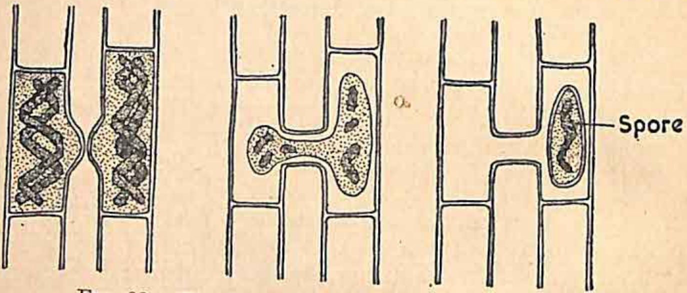


FIG. 68. The Reproduction of *Spirogyra* (*enlarged*).

When reproduction is about to take place two threads of Spirogyra approach and lie side by side (Fig. 68). Outgrowths appear in cells lying opposite each other, and increase in size until they meet and form a bridge. Across the bridge the contents of one of the cells pass into the other cell and unite or fuse with its contents. A thick wall is formed round the fused mass, and the latter becomes a spore which can exist for some time without development should the external conditions be unfavourable for growth. When the conditions become favourable again the spore germinates and a new Spirogyra filament is formed.

As you must have realised, this form of reproduction is much more complicated than the simple division into two daughter cells found in Pleurococcus, or the breaking up of the filaments of Spirogyra. There is an actual setting apart of two special cells for the purpose of reproduction and a fusion of the contents of the two cells to form a new individual.

What is the reason for this complicated process? Why is it necessary for the two cells to fuse? It is obvious that by the fusion the resources of the two cells are pooled and the offspring has the benefit of the combined characters of both parents. Investigators have found that this leads to increased vigour and health in the offspring.

Furthermore, the two parent threads differ slightly from each other, and produce a daughter plant which is not exactly like either parent, though it has resemblances to both. The offspring varies from the parents to a greater or less extent, and this variation, as will be seen later, may be of great value to the young plant. When the Spirogyra thread breaks up into fragments and each fragment develops into a new individual, only one parent is concerned in the production of the offspring, and it will almost certainly become an exact replica of the parent. There is little chance of any useful variation being introduced which might aid the young plant in its struggle for existence. For example, should the daughter filament formed by fusion be endowed with a power to grow more vigorously than either of its parents it will have a better start in life. There are many other variations which might be of use to the young plant—for example, the power to make use of the food supply surrounding it more readily than could its parents, or any characteristic, such as unpleasant taste or odour, which might render it unattractive to its enemies and so encourage them to leave it alone.

There are many plants showing varied and interesting types of reproduction which are more complicated than Spirogyra but simpler than the flowering plant. You may learn about some of these later. In the meantime the descriptions of Pleurococcus and Spirogyra will serve to show that throughout the plant kingdom there are two kinds of reproduction: that in which there is no fusion of two cells and therefore no increase in vigour and little chance of variation, whilst in the second kind there is fusion of two cells and therefore increased vigour and a chance that useful variations may occur.

## Reproduction in the Flowering Plant

Let us now turn to the consideration of the process of reproduction in the flowering plant. We find that many flowering plants can produce offspring in both of the ways described above.

**Vegetative Reproduction.** Many plants produce buds which grow out into shoots when the season is suitable. In some cases these buds can be removed from the parent plant and, when put into a position where they can obtain food and shelter, they continue to grow and a new plant is formed.

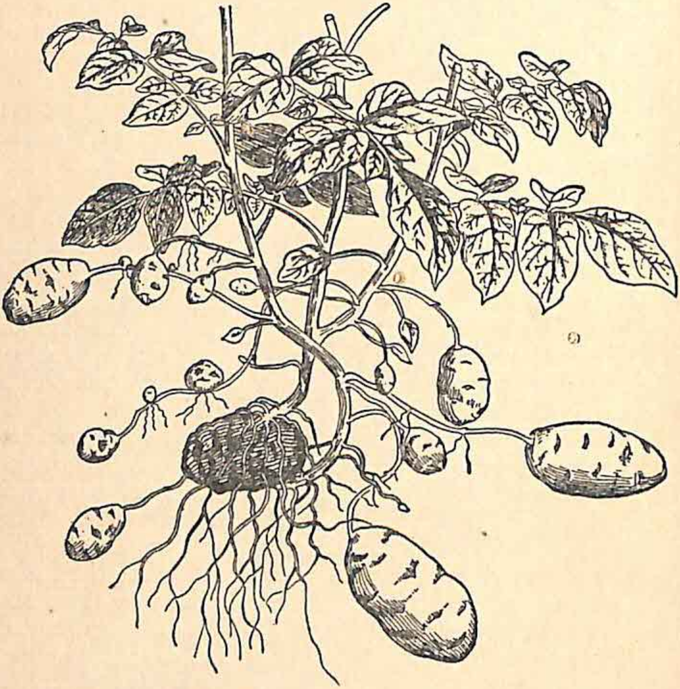


Fig. 69. The Potato Plant.

The gardener uses this method when he 'buds' a rose. It is impossible to describe the process of 'budding' here, but ask your gardener friends about it.

The potato plant produces in the soil those swollen bodies which you know so well and like to eat. Each swollen potato, with its store of food, can produce a number of shoots if planted, and so give rise to new potato plants (Fig. 69).

In rose and potato the above method of reproduction gives rise to plants exactly like the parent. This is of advantage to the farmer and the rose grower because they can be certain of obtaining the kind of potato or rose they require, and so can satisfy the demand for special types of potato or rose.

**Reproduction by Fusion.** The flower is the special structure to which this type of reproduction is entrusted. You have already studied the flower (Chapter II) and know the purpose of each part of it.

The two most important structures in the flower are the *andrœcium* and the *gynœcium*. The andrœcium, as you have learned, consists of a number of stamens which produce the pollen. Examine some pollen grains under the microscope. You will find that they are very minute—many thousands would go on a pinhead. The coat of the grain is often very beautifully marked (Fig. 70). Pollen grains vary greatly in size, shape, and the markings found on their coats; in fact there is a special type of grain for each different kind of flower. Experts can tell by examining pollen grains under the microscope the species of flower from which they come. One expert is able to distinguish different kinds of honey by noting the kind of pollen grains present.

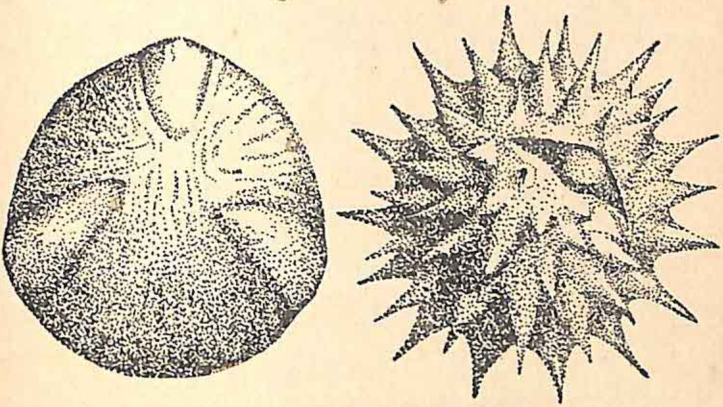


FIG. 70. Pollen Grains of Sycamore and Sunflower (*much enlarged*).

**Pollination.** When the pollen grains are ripe they are shed from the stamen and conveyed to the stigma of the same flower or of another flower. The process of transferring the pollen from the stamen to the stigma is termed pollination.

There are two kinds of pollination, self-pollination and cross-pollination. In self-pollination the pollen is transferred from the stamen to the stigma of the same flower. In cross-pollination it is transferred from the stamen of one flower to the stigma of another of the same kind.

**Self-pollination.** Self-pollination is a very sure method, for the pollen has no distance to travel. In a flower adapted for this type of pollination the anthers of the stamens are placed above the stigma and so the pollen readily falls on the latter.

Since the same parent flower produces both pollen grains and ovules there is little chance of variation, and the offspring will resemble the parent closely. On the one hand this is of advantage, because the grower will be sure of obtaining the type of plant required. On the other hand there is little chance of variations which might be useful in producing new and better varieties of the plant.

There is another serious disadvantage of self-pollination. Although, as you will see later, there is a fusion of the contents of the pollen grain with part of the contents of the ovule, and therefore there should be some increase in the health and vigour of the offspring, scientists have proved that this is generally not so great as it is when the pollen grain and ovule are formed by different flowers.

**Agents which carry out Cross-pollination.** In cross-pollination the pollen grains must be carried from one flower to another. The two most useful agents for this purpose are the wind and insects.

In wind-pollinated flowers the pollen grains must be so light that they can be blown about readily. They must also be numerous, for 'the wind bloweth where it listeth,' and much of the pollen is wasted. The flower is often small and inconspicuous, with no showy petals, because attraction of the agent is not necessary.

Many of the trees, such as poplar, hazel and alder, are pollinated in this manner. The stamens are arranged in long, swinging catkins (Fig. 71), so that the pollen can readily be blown away. The carpels are found in different flowers, and the stigmas often hang out so that they can catch the pollen grains easily. Furthermore, the trees generally flower before the leaves come out, so that the pollen can get away freely. In some trees, such as the poplar, the male and female catkins are on different trees, whilst in the oak and the pine and others they are on the same tree.

Flowers which are insect-pollinated, for example by the bee, are usually attractive in appearance, with a bright colour and a sweet smell in order to tempt insect visitors. Nectar is provided by the flower, and the bee converts this into honey for use in the hive. As an example of cross-pollination by insects let us consider the antirrhinum or snapdragon.

The flowers of the antirrhinum are arranged on a long stalk with the youngest flower at the top and the oldest at the foot (Fig. 72). The bee will probably alight at the tip of the flower stalk, so that it will visit one of the youngest flowers first. In the younger flowers the stamens are ripe but the stigma is not yet ready to receive pollen. The bee alights on the platform formed by the lower lip of the corolla of the flower. It presses this down and, as it does so, causes the ripe stamens to bend down and dust the bee's back with pollen. After sipping the nectar the bee flits to an older flower lower down the stem. The older flower has shed its pollen and the stamens have withered, but the stigma is ripe, and when the bee alights on the lower lip of the corolla it bends down and obtains some of the pollen previously deposited on the back of the bee. Thus cross-pollination is made almost certain by the fact that the stamen and the stigma are not ripe at the same time.

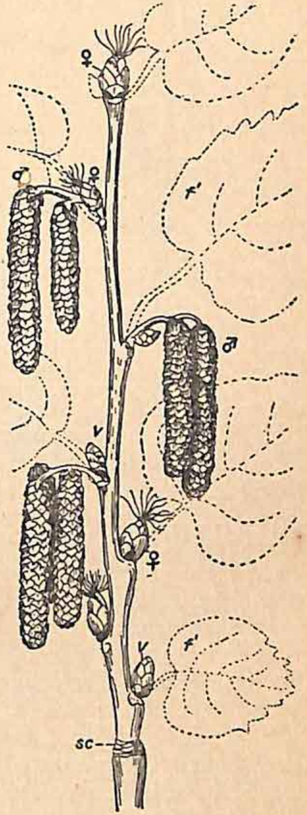


FIG. 71. Shoot of Hazel, with catkins and female flowers.

Unfortunately, some of the bees which visit the antirrhinum are pirates, and steal the nectar without paying the fair price in pollen. If you look very carefully you may find at the base of the flower a tiny round hole. This has been made by a bee which has been too lazy to push its way down between the petals. It knows that the nectar is at the foot of the flower, and takes the easiest way of getting at it by piercing a hole through the base of the petal and sucking at the nectar.

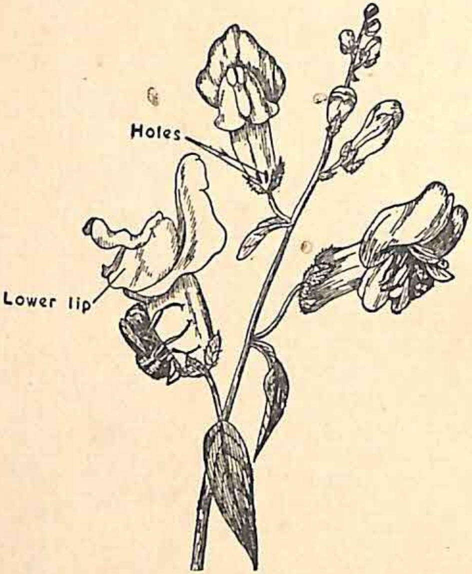


FIG. 72. Flowering Shoot of Antirrhinum, showing pollination by bees.

Although the sweet-pea, with its attractive smell and beautiful flower, is so well adapted for cross-pollination it is almost always self-pollinated. It is said that, owing to cultivation, the flower has become so large that the bee is unable to open the two petals which form the keel (Fig. 73), and so the pollen it requires cannot enter from outside. The flower of the tobacco, which smells so sweetly at night, is also self-pollinated.

Growers can plant different varieties of sweet-pea, for example blue and white, next to each other, and the seed from each is always true to type—that is, seed from a white sweet-pea always gives white, and seed from a blue sweet-pea always blue, flowers. There is no mixing of colours as there would be if cross-pollination had taken place. It is the same with the tobacco flower; varieties of tobacco can be grown side by side without crossing. Many of the important crops, such as wheat, oats and barley, are self-pollinated. The pollen and stigmas are ripe before the inconspicuous flowers open, and the pollen has been transferred to the stigma from its own stamens before it is possible for the pollen from another flower to reach it.

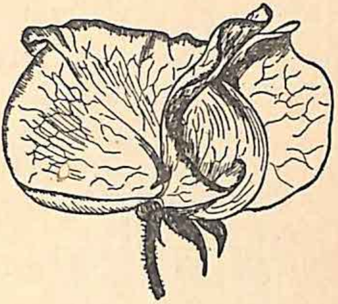


FIG. 73. Flower of Sweet-pea.

**Fertilisation.** When the pollen grain has alighted on the stigma of the flower it soon commences to grow. A long pollen tube grows down the style until it reaches the ovary (Fig. 74). As it grows, the pollen tube dies out behind and its connection with the pollen grain is lost. The tip of the pollen tube, after it has reached the ovary, grows across to the ovule, which it enters by the micropyle; then the contents of the tube fuse with some of the contents of the embryo sac, resulting in the formation of a seed containing a minute plant and a store of food to help it when it commences to grow in the following spring. The fusion of the contents of the pollen grain with part of the contents of the embryo sac is termed 'fertilisation.'

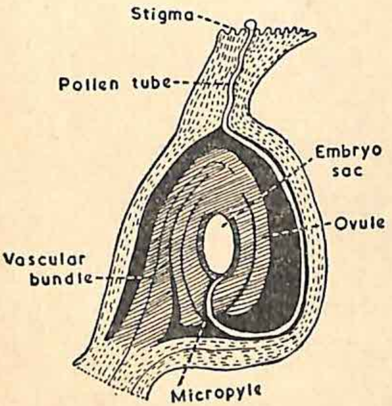
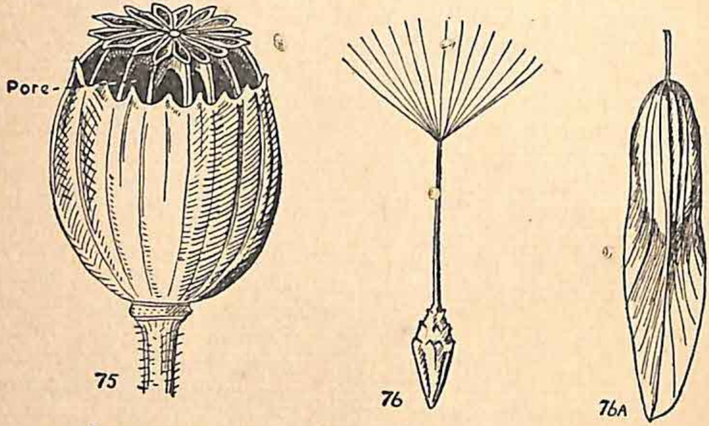


FIG. 74. The Fertilisation of the Ovule by the Pollen tube (*enlarged*).

**The Fruit.** The entire structure formed as a result of fertilisation is the fruit. Usually it consists of the ripened ovary containing the ovules which have now become seeds. Sometimes, however, other parts of the flower, for example the calyx, and even the tip of the flower stalk, remain and aid in forming the fruit.

The two main duties of the fruit are, firstly, to protect the seeds, particularly against excessive loss of water. Secondly, the fruit is often adapted to aid in dispersing the seeds when they are ripe. If the seeds just fall down and, next season, commence to grow at the base of the parent plant they would probably suffer from overcrowding and, as in the case of human beings, will not flourish, for the food supply will be inadequate and they will have insufficient air and light.



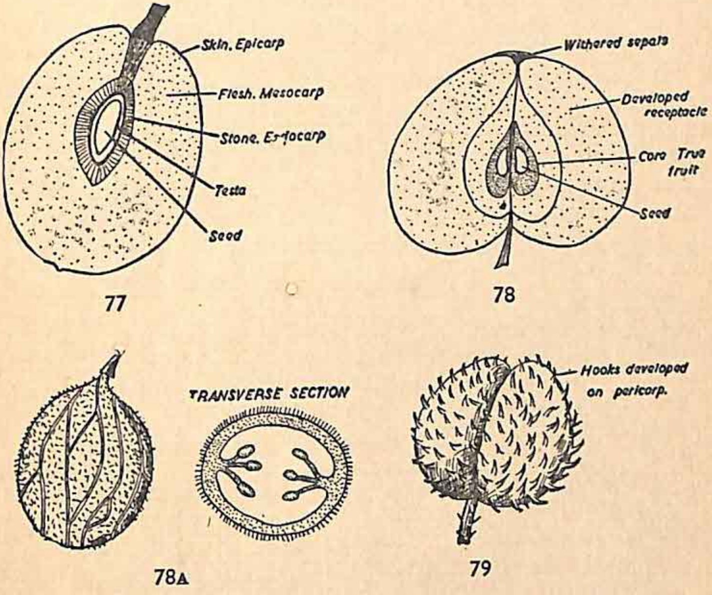
FIGS. 75–76A. The Distribution of Seeds and Fruits.
75. The Poppy; 76. The Dandelion; 76A. The Ash.

So that it can fulfil its first duty satisfactorily the fruit often develops a hard, strong coat, for example the nut. If the fruit does not develop this protective covering the seed itself may be furnished with a hard coat, for example the gooseberry and currant.

In regard to its second duty, the spreading of the seed, the fruit shows a number of special adaptations, but we can consider only one or two of these. As in pollination, the two agents, wind and animals, have an important part to play in seed dispersal. Let us first consider a few examples of fruits which rely upon the wind.

(1) *The Poppy.* The seeds of the poppy are very minute and so are readily carried to a great distance by the wind.

The fruit, called a capsule, is carried on the top of a slender stem which sways to and fro in the wind. As it moves the seeds are shaken out through little holes or pores (Fig. 75) underneath the stigma, just like pepper from a pepper-pot.



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78A 79

FIGS. 77–79. The Distribution of Fruits and Seeds.
77. The Plum; 78. The Apple.
78A. The Gooseberry; 79. Goose-grass.

(2) *The Dandelion.* The flower-head of the dandelion produces a large number of tiny florets which give rise to tiny fruits. Each little fruitlet (Fig. 76) consists of an ovary containing a single seed and a parachute of fine silky hairs which enables it to be carried readily through the air.

(3) *The Ash.* The fruit coat of the ash (Fig. 76A) is prolonged into a wing which is caught by the wind, and so the fruit with its single seed is blown to some distance from the parent plant.

Let us now turn to those fruits which are dispersed by animals and consider several examples.

(1) *The Plum.* The fruit coat of the plum (Fig. 77) is divided into three parts. The outermost part forms a thin skin which can easily be peeled from a ripe fruit. The central portion is fleshy, and the innermost part forms a stony covering to protect the seed within. The animal eats the fleshy part and drops the stone, probably in some position where the seed may be able to germinate next season. The fruit of the plum is called a 'drupe.'

(2) *The Apple.* The fleshy part of the apple (Fig. 78) is formed from the top of the flower stalk which grows up round the fruit coat and protects it. The fruit coat is the horny or 'cartilaginous' core within which are found the seeds with their protective brown coats. In the case of the apple an animal may eat the fleshy portion and swallow the seeds. It cannot digest the seed coat and so the seeds pass through the body of the animal unharmed. The fruit of the apple is called a 'pome.'

(3) *The Gooseberry.* In this fruit (Fig. 78A) the seeds are embedded in pulp formed by the inner layers of the fruit coat. They are shed in the same way as those of the apple. The animal eats the juicy portion of the fruit and the seeds pass through the food canal unharmed. The fruit is called a 'berry.'

(4) *Goose-grass, Cleavers, or 'Sticky Willie.'* The fruit (Fig. 79) of this plant is not fleshy but it is provided with a large number of hooks. These catch on the coat of an animal as it pushes its way through the hedge in which the goose-grass is growing. When the animal pushes its way through another hedge the fruits may be removed from its coat and can settle down in their new position to germinate in the spring.

There are many other ways of seed distribution, but the above examples will serve to illustrate those most commonly used.

In whatever way the seeds are spread, they usually lie dormant during the cold months of winter and commence to grow when the warmer days of spring arrive. The life-story of the plant then commences once more.

## CHAPTER XII

# REPRODUCTION IN ANIMALS

COMPARISON WITH THAT IN PLANTS – REPRODUCTION OF SOME SIMPLE ANIMALS – REPRODUCTION OF SOME MORE COMPLEX ANIMALS – SUMMARY

### Comparison with Reproduction in Plants

It was shown in the previous chapter that there are two types of reproduction found in plants.

(1) *Vegetative Reproduction.* In this type the offspring have only one parent, and therefore the chances are that they will resemble that parent very closely.

(2) *Reproduction by Fusion.* In this type two parents are involved, and therefore there is a chance of variation. The basis of this type of reproduction is the fusion of two cells, a process which favours increased vigour in the offspring.

As we study the reproduction of certain animals we must look out for these two types, though it will be better to find another name for the first one, *asexual*, or without fusion. This term can be used in the case of both plants and animals, but the term *vegetative* is suitable only in the case of plants.

### Reproduction in some Simple Animals

**Amœba.** You have already been told that Amœba is a single-celled animal which can carry out all the necessary life processes, nutrition, respiration, reproduction, growth (Fig. 63).

As in the single-celled plant, Pleurococcus, the process of reproduction is extremely simple. The nucleus of the cell divides, followed by a division of the cell itself into two daughter cells. The daughter cells grow until they reach adult size and the process of division may then be repeated. Amœba reproduces, therefore, in the same way as Pleurococcus, by the method of simple fission.

No method of reproduction by fusion has yet been established in amœba.

8

**Hydra.** In this little animal both kinds of reproduction are found.

(1) *Asexual Reproduction.* If you are lucky enough to have some specimens of hydra flourishing in your aquarium you may find, on examining several of them, that one or two may show little swellings on the side (Fig. 64). Try to keep one of these swellings under observation under the low power of the microscope. You may find that it increases in size and, finally, becomes a miniature edition of its parent.

As soon as it is large enough to become independent, the baby hydra is detached from the parent and enters upon a separate existence. This method of reproduction is known as 'budding,' and there are many examples of it, particularly, as we have seen, in the plant kingdom.

(2) *Reproduction by Fusion.* If conditions are not very favourable, for example if the food supply is scanty or the temperature is low, hydra may reproduce by the second method. Little swellings also appear, some high up under the mouth with its waving tentacles, and others much lower down near the base.

To examine one of the swellings just under the mouth very high powers of the microscope are required. You will probably have to rely on diagrams for your investigation of this structure. It is the male organ and is called the testis. Unlike the swelling described under asexual reproduction this organ does not increase in size to any great extent. Development takes place within it, large numbers of tiny specks of protoplasm being formed. Each tiny speck is provided with little whips of protoplasm which enable it to swim about. The tiny bodies are called sperms.

The examination of one of the swellings lower down is perhaps easier as regards size, but they are not so numerous as those higher up. This swelling is the female organ and it is called the ovary. It contains one large body, the egg.

Sperms and eggs may be formed on the same animal, but usually the sperms from one hydra swim to the eggs of another and fuse with them. As was the case in plants, this process of cross-fertilisation leads to healthier offspring. Only one sperm fuses with each egg.

The result of the fusion of egg with sperm is the formation of a round, thick-walled spore. Because of its thick wall the spore can resist unfavourable conditions, such as the drying up of the water in which hydra are living. When conditions are favourable once more the spore will germinate and give rise to a new hydra individual.

Both types of reproduction are much more complicated than the process of simple fission found in Amœba, showing that Hydra is higher up the scale of animal life.

**The Earthworm.** The process of reproduction by fusion has already been described on p. 22. As stated there, eggs and sperms like those described in hydra are formed, and both are present in the same animal. As in the case of hydra cross-fertilisation takes place.

Is there any asexual type of reproduction in the life-story of the earthworm? The only traces of it are seen when a worm is accidentally cut into two parts. Each part can proceed to grow a new head or tail as the case may be. This is not always possible. If the head portion is small—that is, the worm has been cut into two quite near the head—both portions can grow new tail or head, and they can do so if the worm is cut near the centre. If, however, the worm has been cut near the tail end, the head part can grow a new tail but the tail part cannot grow a new head. Several explanations of this inability have been given. Perhaps the simplest to understand is the following. The head part contains a simple brain and this takes a great deal of material to replace it, so that if the worm is cut too near the tail there is not sufficient material present to form a new brain in the smaller portion. This is not a natural type of reproduction, and the worm relies mostly on the fusion type for the preservation of the species.

## Reproduction in some Higher Animals

**The Fish** (see p. 35). Sperms and eggs are produced but, unlike hydra and the earthworm, they are not present in the same animal. The sperms are produced by the male fish and the eggs by the female fish.

Many of you will have eaten so-called 'hard' and 'soft' roes. The hard roe is made up of a large number of eggs and the soft roe of a much larger number of sperms. As stated before, the male pours the sperms over the eggs and fertilisation takes place in the water.

There is no asexual method of reproduction.

**The Frog.** In the frog also (p. 14) eggs and sperms are produced in different individuals. Fertilisation takes place outside the body of the mother in the water, but the male makes sure that the eggs are duly fertilised at the right time by attaching himself to the female while she is laying her eggs. In the fish, as in the frog, eggs and sperms are produced in great numbers and many perish in each animal.

**The Bird.** In the bird a great advance in the method of reproduction is made. The male bird actually places the sperms in the body of the female and fertilisation takes place within. When the eggs are laid they are ready at once to commence development into new individuals.

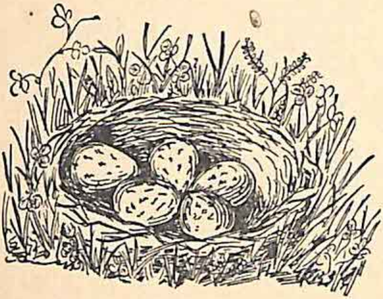

Fig. 80. A Skylark's Nest and Eggs.

Linked with this much more careful method of fertilisation is one of the most beautiful examples of parental care in the animal world. When mating time arrives, the first action of the parent birds is to provide a suitable home for the little ones so soon to be with them (Fig. 80). The male bird spends time and much labour in preparing a cosy nest, which the eider-duck, for example, lines with down from her own breast.

When the eggs are laid the mother protects them with her own body so that they do not become chilled. In some species of bird the male bird may take his share in sitting on the nest so that the mother may have an opportunity to stretch her wings. In any case, he generally feeds her while she is sitting. The blackbird about which I told you on page 35 used to bring his wife off her nest for a few minutes every morning about nine o'clock, and guard her while she pecked about for a short time.

At last the care and patience of the parents are rewarded. Usually in two or three weeks the baby birds hatch out and then still greater activity on the part of the parents is required. The babies appear to be all mouth, and are always clamouring for food. Father and mother devote themselves to providing food for the hungry youngsters.

There was a very touching story told by a keen lover of nature in the columns of a magazine a little while ago. Two pairs of partridges had built their nests close together on the ground. One of the male birds was killed, and the second male adopted his friend's family and helped both mother birds in feeding their young.

Mammals. The highest animals, including man himself, belong to the group known as the *Mammals*. In members of this group parental care reaches still more wonderful heights. The baby is protected for some time within the body of the mother herself until it is better fitted to withstand the rigours of life in the outside world.

But parental care does not cease with the actual birth of the baby. In a sense it only begins then. Your pet cats and dogs belong to the group of the mammals. Have you ever watched a cat protecting her kittens and defying any stranger to approach them? She is very proud, however, to show off her precious babies to those she knows and trusts. The cat also teaches her family to obtain their food, and prepares them for life in the world into which they have been born.

## Summary

There are two main principles which I want you to grasp as a result of reading this chapter.

(1) *As we proceed from the simpler to the higher animals in the study of reproduction the process becomes more and more complicated.* In Amœba it is a question only of the simple division of the cell into two parts which are exactly alike. In the bird and the mammals there is a precise and sure method of fertilisation associated with a great provision for the protection of the young.

Associated with the development of a more complicated process of sexual reproduction the asexual type of reproduction has been dropped by the higher animals. The type depending on fusion, with its great advantage in the production of more vigorous and healthy offspring, has been established.

(2) *The care of the offspring in its early stages has been developed to a great degree.* In animals quite high in the scale of development the parents are very indifferent to the fate of their babies. For example, the fish and frog, as soon as the eggs are laid and covered with the fertilising fluid, go off in a carefree manner and leave their offspring to fend for themselves.

On the other hand the human parents make themselves responsible for their children throughout their childhood, and often until early manhood or womanhood has been reached.

To make up for the great mortality amongst their young, due to the lack of parental care, the frog and many of the fishes, for example, lay numerous eggs. The bird lays only a definite number of eggs, often only four or five, though it may lay as many as twelve or more, as in the case of the pheasant and grouse. The parental care lavished on the young ensures that the rate of mortality is small, so that it is not necessary for so large a number of offspring to be produced.

The human baby usually has a good chance of reaching manhood or womanhood because of the care and attention devoted to it, so that only one as a rule is born at one time. Thus the mother has more time to devote to the child than if she had a large number to care for.

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# CHAPTER XIII

# MAN

Various Systems developed to carry out Different Functions – Skeleton – Respiratory System – Circulatory System – Alimentary System – Excretory System – Reproductive System – Nervous System

We thus come to the consideration of Man, the most complicated of all the animals. We found that in some of the higher animals, the fish and the frog, for example, various systems have been developed which are adapted for the various functions they have to perform. These systems are still more highly organised in man. They will be dealt with briefly in this chapter, and three of them will receive fuller consideration in following chapters.

## The Skeleton

The bony skeleton in man consists of over two hundred bones. These are divided into three main groups.

(1) *The Head.* The head consists of skull and face bones. The skull (Fig. 81) is made up of a number of bones which fit closely together. It forms the top and back of the head. Examine a skull carefully and you will find wavy lines which show where the various bones interlock with each other. This wavy suture, as it is called, forms a very compact and strong junction, and so renders the skull more efficient as a protection for the delicate brain within.

If you examine the head of a baby you will find that there is quite a large gap between the bones of the skull on the top. They have not yet united, as they will do later. Therefore the head of a baby must be protected from all external injury, such as a fall, which might do irreparable damage.

The structure of the bones forming the skull, especially that at the base of the skull, is more compact than that of the other bones of the body. To prevent the head being too top-heavy there are several air-spaces in the skull, but the substance of the bones themselves is very dense and affords a strong protection for the brain.

If you are able to carry it out the following experiment will prove interesting to perform. Obtain the clean dry bones of a rabbit, which may be prepared by gently simmering bones collected after a dinner of rabbit, taking care that the bones are not broken. They should be simmered until any flesh remaining can be readily scraped away. Allow them to dry thoroughly, and then select the skull and one of the large bones of the leg. Cut the shaft of the leg-bone just below the head and above the cavity in the shaft. Weigh the head of the leg-bone and the skull and find their volumes by the method of displacement and calculate the densities. You will find that the density of the top of the leg-bone is less than that of the skull-bone.

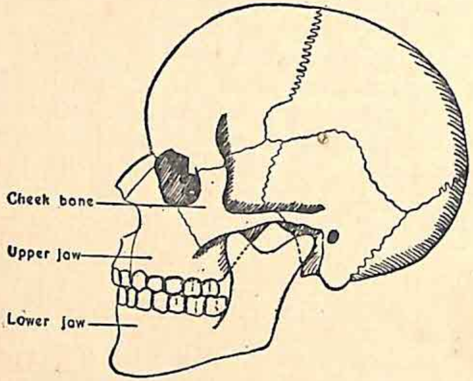

FIG. 81. The Skull.

A number of bones form the face; the most conspicuous are the jaw-bones which hold the teeth and the cheek-bones which give the shape to the face (Fig. 81).

(2) *The Trunk* (Fig. 82). This includes the back-bone, breast-bone and ribs. These bones are not so firmly attached to each other as are those of the skull. They are jointed so that movement is possible.

The back-bone is made up of a great number of bones (Figs. 82 and 90) each called a *vertebra*, so that it is often known as the *vertebral column*. These bones do not move very freely, but allow of sufficient movement to turn our bodies from side to side.

The ribs are attached to the vertebral column, and all except the three lowest pairs are also attached to the jointed breast-bone. There are muscles between the ribs which have an important part to play in the process of respiration.

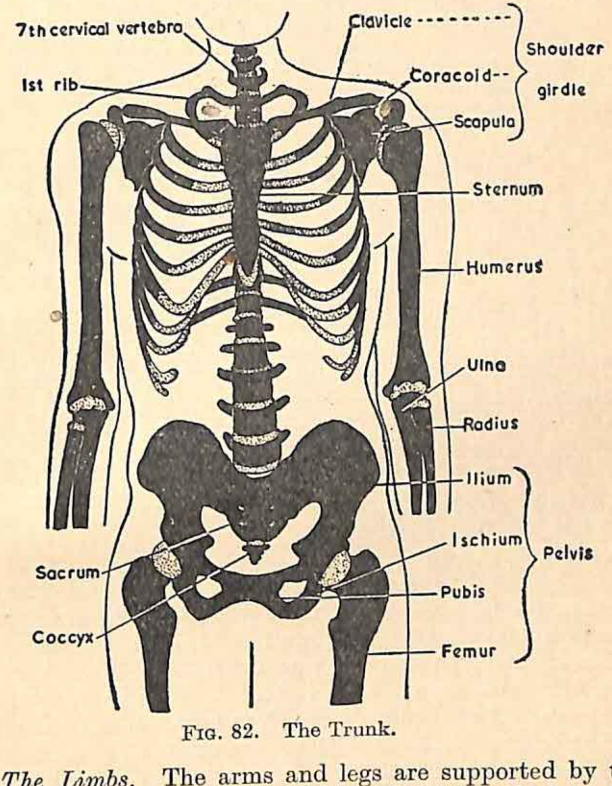

FIG. 82. The Trunk.

(3) *The Limbs.* The arms and legs are supported by the third set of bones. Each pair of limbs is attached to the trunk by a girdle of bones (Fig. 82). The shoulder girdle consists of two scapulæ (shoulder-blades) which are connected to the breast-bone by two clavicles (collar-bones). In the lower girdle, connecting the legs to the trunk, the pelvic bones are the most important. They fuse to form the basin-like pelvis which protects some of the delicate bodily organs. The

pelvis has also much to do with movement in walking and with our ability to maintain an upright carriage.

**Uses of the Skeleton.** These are two in number:

(1) It forms a firm foundation to which the muscles are attached and so they are enabled to perform the movements essential for life.

(2) It forms a protection for the delicate inner organs such as heart, lungs, liver, brain and spinal cord.

Alimentary, respiratory and circulatory systems will be dealt with in succeeding chapters.

## The Reproductive System

Those of you who intend to make medicine your future career will study the reproductive system in detail during your medical course. Sperms and eggs are produced by the different sexes, as in fish, frog and bird. The sperms are placed inside the body of the female, and the baby is protected there during the first nine months of its existence.

The wonderful care of human parents has already been mentioned.

## The Excretory System

The chief duty of the excretory system is to expel waste material, so that it does not give rise to harmful poisons throughout the body.

The excretory system consists of *kidneys*, and long tubes (*the ureters*) which connect them with the *bladder* (Fig. 83). In the kidneys are collected all waste products in solution which should be removed from the body. The kidney is a most important organ. If it fails to function properly the whole body is upset and the patient becomes very ill.

The waste liquid material passes down the tubes into the bladder, from whence it is emptied when the latter has become full.

The waste material in the body is dissolved in water in the kidneys. In order that all the waste material may be excreted a definite small quantity of water is necessary every day. Any excess water is also expelled through the kidneys. If a large quantity of water is drunk, the waste material will be expelled as a weak solution.

The skin has also a certain amount to do with excretion; it passes out through its pores a large amount of water containing salt. It is largely by the evaporation of this water that our bodies are kept at a constant temperature. It is very important that people working in very hot conditions should drink plenty of water to which a little salt has been added. Stokers on our great liners often used to suffer from a condition known as 'fireman's cramp.' This caused great pain in the limbs and was always brought about by drinking a lot of water. It was discovered that the addition of salt to the water drunk prevented cramp. This is because the salts present in the perspiration given off by the skin have to be replaced.

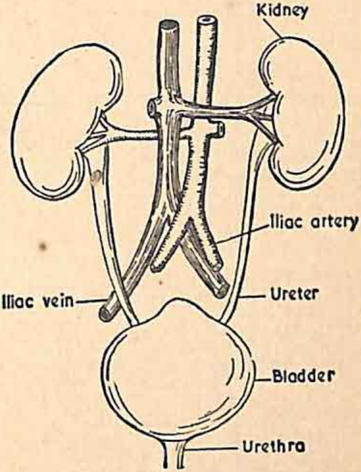

FIG. 83. The Excretory System.

If the pores are choked so that the skin cannot function properly death may result. This is illustrated by the following story. A famous dancer once had her body completely covered with gold leaf for some important festivities at which she was to dance. It was some considerable time before the gold leaf was removed, and before this could be accomplished she died because her temperature had become abnormally high; in other words she was suffering from intense fever. This shows how important it is to keep the skin clean by frequent bathing.

Carbon dioxide is a waste product of the body. It is carried by the blood stream to the lungs and then passes into the expired air. Thus the lungs, as well as the kidneys, take part in the excretion of waste material from the body.

## The Nervous System

This system is very difficult to dissect and examine. It needs expert guidance for its investigation and little will be said about it here.

The nervous system is made up of brain, nerve-cord, and an intricate system of small and large nerves conveying messages to and from the brain and spinal cord.

In the higher animals the messages from the outside world are sent to the brain or spinal cord, where they are interpreted, and a message is sent by another part of the nervous system to the muscle which has to carry out the response to the message. For example, if you put your finger on a hot stove, a message of pain passes to the spinal cord. This receives the message, and a reply is sent down another set of nerves to the muscles in the finger, so that they contract and the finger is lifted (Fig. 84).

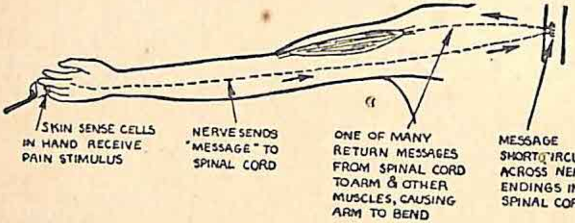
SKIN SENSE CELLS IN HAND RECEIVE PAIN STIMULUS
NERVE SENDS "MESSAGE" TO SPINAL CORD
ONE OF MANY RETURN MESSAGES FROM SPINAL CORD TO ARM & OTHER MUSCLES, CAUSING ARM TO BEND
MESSAGE SHORTCIRCUITS ACROSS NERVE ENDINGS IN SPINAL CORD

FIG. 84. Diagram of Path of Nerve Impulse from the Hand to the Spinal Cord (Nerve Cord).

Lowly animals like Amœba have no special nervous system. The nervous system becomes more complex in the higher animals and reaches its highest development in man.

Man, because of his highly developed nervous system, is capable of reason, and therefore has greater sources of joy and pain than any other animal. He is capable of controlling his own life in a way no other creature can do.

Illness of the nervous system may affect any part of this system and must be treated by a doctor whose advice must be carefully followed. There is every chance of a complete recovery in a mental disease which affects the brain and is often known as a 'nervous breakdown.'

## CHAPTER XIV

# NUTRITION IN MAN

COMPARISON WITH ANIMAL NUTRITION (CHAPTER X) – FOOD-STUFFS REQUIRED – COMPARISON OF ALIMENTARY CANAL WITH THAT IN A LOWER ANIMAL – HOW DIGESTION IS ACCOMPLISHED IN MOUTH, STOMACH, ETC. – ABSORPTION THROUGH THE INTESTINE – USES OF FOOD

### Comparison with Animal Nutrition

In Chapter X nutrition in animals was described. It was pointed out that the animals are dependent on other animals and plants for their food supply. This is equally true of man, the most highly developed of all animals.

On the whole, the method of nutrition in man resembles that found in higher animals, such as the fish and rabbit. The same food-stuffs are required, and the food-canal, which renders them suitable for use, is built on similar lines.

### Food-stuffs Required

As stated before the food-stuffs fall into three classes: (1) body-building, (2) energy-producing, (3) protective. In addition, water containing salts in solution and vitamins must form part of the diet.

What food-stuffs are required for these purposes and whence are they obtained?

(1) *Body-building Foods.* The *proteins* are the most important. They are found in both plants and animals. Lean meat, eggs, milk, peas, beans, lentils contain them. Animal proteins are more efficient in body-building than plant proteins.

(2) *Energy-producing Foods.* *Fats* are found in fat meat, milk, butter, cream, eggs, and oils from nuts and other plant-storage organs, e.g. olive-oil and almond-oil. Some of these oils are present in margarine. An animal oil, from the whale, is largely used in making margarine.

*Sugars* can be taken in the pure condition, or in the form in which they are found in fruits, such as bananas and apples, and also in milk and eggs. *Starch* is found in flour, oatmeal, potatoes.

(3) *Salts of iron, phosphorus, calcium, etc.* are found in green vegetables such as spinach, cabbage, lettuce, and also in milk. Milk, however, is deficient in iron. Iron is present in comparatively large amounts in oatmeal, altogether a very valuable food.

(4) *Vitamins* are found in fresh vegetables and fruits, and also in eggs, butter, milk. Some are found in oils, such as halibut and cod-liver oil. Important vitamins are also present in the cereals, especially in the outer coats of the grain; therefore there is more vitamin in brown bread which contains the 'bran' than in white bread. Oatmeal is a valuable source of vitamins. The presence of vitamins in the diet is so important that steps have been taken to add one or two of the most important to bread and margarine.

(5) *Water* is present in many food-stuffs. In order that the body may obtain sufficient water, a variable quantity must be taken apart from that in the food.

In reading through the above you will have seen that milk is a very important food. It contains examples of all the main classes of food-stuffs but is deficient in iron and certain vitamins. For children in their earlier years it is the most suitable food. It has definitely been proved that the health of those children who take advantage of school milk schemes has improved considerably. They have gained in height, weight, and resistance to disease.

## Food Canal

It has been stated previously that the food or alimentary canal of man (Fig. 85) is built up on the same lines as that in the higher animals, such as the rabbit (Chapter X).

Food is taken in at the mouth, where it is chewed or masticated by the teeth, assisted by the tongue. The tongue helps to roll the food round, mixes it with saliva, and returns it to the teeth until sufficiently masticated.

Look at Fig. 86 and you will see that the human being has three types of teeth.

(1) *The incisors* in the front have sharp, knife-like edges for cutting up the food.

(2) *The canines* and bicuspids aid the incisors in breaking up the food. They are sharp-pointed like those of a dog.

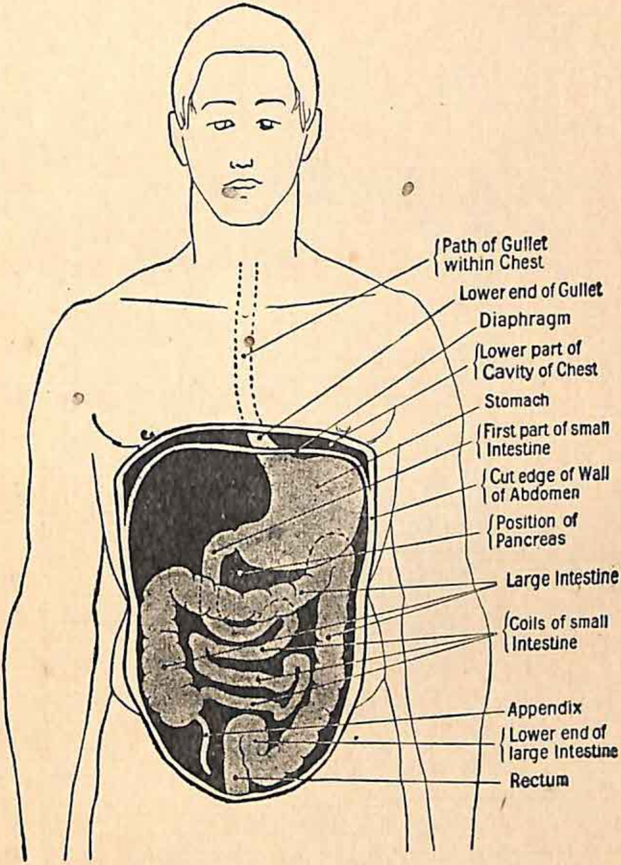
Path of Gullet within Chest
Lower end of Gullet
Diaphragm
Lower part of Cavity of Chest
Stomach
First part of small Intestine
Cut edge of Wall of Abdomen
Position of Pancreas
Large Intestine
Coils of small Intestine
Appendix
Lower end of large Intestine
Rectum

FIG. 85. Diagram of part of the Alimentary Canal. The coils of the small Intestine are shown.

(3) *The molars* are further back in the mouth. They have a flat, grinding surface like those of the cow, and are used for chewing the food broken up by incisors and canines.

The form of the teeth which man possesses shows that he is adapted to be an omnivorous animal; he can eat and digest both flesh and vegetables. The dog is adapted to eat flesh and has well-developed canine and incisor teeth; the cow,

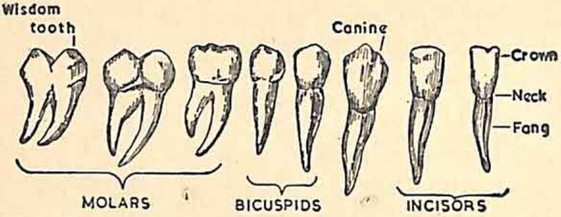

FIG. 86. Teeth of Man.

which is adapted to eat grass and other material, has large molar teeth with ridged surfaces (Fig. 87).

From the mouth the food passes into the stomach. From the stomach it passes into the small intestine, from the small

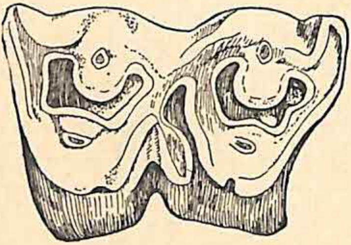

FIG. 87. Surface of Molar Tooth of Cow.

intestine into the large intestine or colon, from the large intestine into the rectum, and the residue to the exterior through the anus (Fig. 88).

## How Digestion is Accomplished

We have traced the course of the food through the food canal. Let us now consider what happens to it during its passage, remembering that the main food-stuffs are sugars and starches, proteins and fats.

The chief purposes of digestion, as stated previously, are to break down the complex food-stuffs, and to convert them from the insoluble form to the soluble form so that they can be absorbed by the body.

This process commences in the mouth. The food is chewed into small pieces by the teeth and mixed with saliva secreted by the salivary glands. In the saliva is present an enzyme called ptyalin. This acts on the insoluble starch and converts it into soluble sugar.

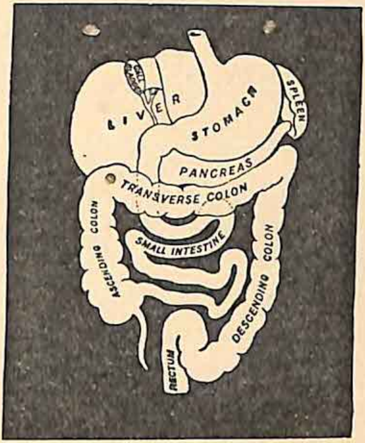

FIG. 88. Diagram of Stomach and Intestine and adjacent organs.

Before we go any further let us be sure that you understand what an *enzyme* is. An enzyme is a complex chemical substance, produced by the body. The work it does is well known, but the way in which it carries out this work is very complex, and is not yet fully understood.

You will remember that when you collected supplies of oxygen you used potassium chlorate and manganese dioxide mixed together. The purpose of the manganese dioxide was to cause the potassium chlorate to give off its store of oxygen more freely and at a lower temperature. At the end of the experiment the manganese dioxide remained unchanged. A chemical substance which causes a chemical action to take place more readily at a lower temperature is known as a catalyst.

An enzyme is a much more complex chemical substance than a catalyst, but its function is very similar. It enables a complex chemical action, such as the conversion of starch into sugar, to take place readily, but itself remains unchanged at the end of the action.

To return to the digestion of food in the alimentary canal. As stated before, digestion commences in the mouth, starch being converted into sugar by means of the enzyme, ptyalin. The saliva is alkaline and the ptyalin works most effectively in an alkaline solution.

The next process of digestion takes place in the stomach. The walls of the stomach secrete three important chemical substances, the enzymes pepsin and rennin, and in addition hydrochloric acid.

The enzyme pepsin converts most of the insoluble proteins into soluble peptones. Rennin deals particularly with the somewhat indigestible protein present in milk. The rennin causes the protein to clot so that it remains for a longer time in the stomach and is more thoroughly digested.

The hydrochloric acid present in the stomach has the following uses:

(1) It assists pepsin in the work of digesting proteins. Hydrochloric acid neutralises the alkaline food as it passes down from the mouth and renders it acid. Pepsin only works in an acid solution.

(2) It breaks up more complex sugars, like cane sugar, into simpler sugars which can be more readily used by the animal.

(3) It dissolves the hard material of which bones, for example, partly consist. For this reason dogs, which frequently crunch bones, have a larger amount of hydrochloric acid present in their stomachs than have human beings.

(4) It has an antiseptic action, destroying many of the harmful germs introduced into the stomach.

If food is 'bolted,' that is, eaten too quickly, and sufficient time is not allowed for digestion in the mouth, the gastric juices of the stomach are overtaxed. This leads to the secretion of too much hydrochloric acid and it sometimes causes pain. Often the pain can be eased by taking an alkali but this should not be taken too frequently. The advice of a doctor should be sought and the real cause of the trouble, probably insufficient time at meals, or faulty diet, should be investigated and the fault put right.

Digestion is continued in the first part of the small intestine. The part just beyond the stomach forms a loop known as the *duodenum*. In this loop is situated the *pancreas* (Fig. 88). This gland pours pancreatic juice into the small intestine. The pancreatic juice contains several important enzymes. One of these, amylase, converts the bulk of the starch into sugar; another, trypsin, breaks down proteins which have not already been broken down in the stomach; a third, lipase, converts the fats into a form more readily absorbed into the body.

You will notice the *gall-bladder* associated with the liver (Fig. 88). From it a tube called the *bile-duct* passes into the small intestine, and down the tube is poured a sticky, bitter, yellow liquid known as bile.

The main function of the bile is to emulsify the fats. It breaks up the large fat drops into droplets and aids the absorption of these particles of fat through the intestinal wall into the blood stream.

The action of bile can be demonstrated by the following simple experiment. Obtain the gall-bladder of a sheep from your butcher. Slit through the wall and collect the bile in a beaker. Place a little olive-oil in each of two test-tubes, about one inch in depth. To one test-tube add an equal amount of water and to the other an equal amount of bile. Shake up both test-tubes well and note the results. In the first test-tube the olive-oil remains in large drops, in the second the bile has broken it up into fine droplets.

Digestion is now completed by the intestinal juices, which also contain enzymes. During its passage along the rest of the lengthy small intestine the liquid, digested food passes gradually through the wall of the intestine and is absorbed into the blood-stream. The latter carries it to every part of the body which requires it. The process of absorption is very interesting, and the wall of the small intestine is specially constructed for this purpose. However, this subject must be left until you go further into the realms of biology.

The undigested food is dealt with in the large intestine, which is only about 5 feet long in man. Water is extracted from the undigested food as it passes along until it reaches the rectum in a much more solid form. From the rectum it is expelled at regular intervals through the anus.

Proper elimination of undigested food is important, and should be ensured by regular habits and suitable diet. As stated before, retention of undigested food in the body will upset the normal functioning of the alimentary canal and may have a very bad effect upon the health of the individual. Suitable diet is much more beneficial than medicines. It should include a generous supply of brown bread, fruit, fresh vegetables and green salads. The foods mentioned provide what is termed 'roughage,' food material which is not digested but which takes with it undesirable substances which might be bad for health.

## Uses of the Food-stuffs

The uses of the food-stuffs absorbed by man are similar to those in other animals.

(1) *Proteins* are used in building up and replacing body tissue of all kinds.

(2) *Sugars, starches and fats* are chiefly concerned with producing energy so that the life processes can be carried out. Fats are especially useful in raising the temperature of the body if the weather is cold.

(3) *Salts of calcium and phosphorus* are used in building up healthy bones and teeth.

(4) *Salts of iron* are required in small amount to maintain the blood in a healthy condition.

*The vitamins* must now be considered more fully; they are essential for life in man. Since their structure was formerly not known they were all distinguished by letters. Six important vitamins are described below.

(*a*) Vitamin A is found in cod-liver oil, yolk of egg, butter, spinach and all vegetables with a yellow colour, such as carrots and turnips. If it is absent from the diet lack of growth, catarrh and night-blindness result. Its valuable properties are not spoiled by cooking.

(*b*) Vitamin B is found in grain, yeast and nuts. Its absence is responsible for various disorders of the nervous system and alimentary canal, and the disease known as beri-beri and other illnesses. It is destroyed by heat.

(*c*) Vitamin $B_2$ is found in grain, yeast, milk, meat and green vegetables. It resists heat, so is present in cooked vegetables. Its absence causes diseases of the skin, food canal and nervous system.

(*d*) Vitamin C is present in fresh lemon juice, orange juice, peas, beans, cabbages and swedes. Its absence is responsible for scurvy, a skin disease which much afflicted sailors in the old sailing-ship days when fresh vegetables could not be carried. When it became the custom to issue a daily ration of lemon juice no further trouble arose. This vitamin is destroyed by heat.

(*e*) Vitamin D is found in the same places as Vitamin A. It can also be formed by ultra-violet rays present in sunlight. Therefore children should have as much sunlight as possible. Certain new kinds of glass admit these important rays, and such glass is fitted into the windows of some of the newer schools. The absence of Vitamin D is responsible for rickets and faulty teeth. It is destroyed by heat.

(*f*) Vitamin E is present in wheat, lettuce and peas amongst other foods. When an animal lacks this vitamin in its diet no offspring are born. It resists heat.

You will observe from the above list that certain of the vitamins are destroyed by heat and therefore by cooking. Fortunately they can be obtained in raw fruits, salads and cod-liver oil which do not require cooking, and a proportion of these should be included in the diet when possible.

The study of a suitable diet is very important, especially to the mother of a family. By taking thought and trouble she can provide more nourishing food at a smaller cost and so improve the health of her family.

## CHAPTER XV

# RESPIRATION IN MAN

The Composition of the Air which Enters the Lungs – How Entry is Effected – Inspiration – Use of Air in the Lungs – Expiration – Composition of Air Expired – Circulation – Structure of Blood – Uses of Blood – Structure of Heart, Main Arteries and Veins – Use of Oxygen in the Blood

In considering the respiration of man I am going to adopt the usual plan and divide the process into two parts, keeping the term *respiration* for that part of the process dealing with the inspiration and expiration of air, with a description of the mechanism involved. The term *circulation* will be taken to include that part of the process in which the oxygen is carried in the blood-stream to every part of the body that requires it.

### Composition of Air Entering the Lungs

It is found that air entering the lungs in a comparatively fresh atmosphere contains about 80 per cent. nitrogen, 20 per cent. oxygen, and about .04 per cent. carbon dioxide. These proportions will vary a little with the freshness of the atmosphere. In fresh country air the percentage of oxygen may be as high as 21 per cent.

### How Air Enters the Lungs

In the first place air is drawn in through the nose, at least it should be if the individual is breathing correctly. It is important to practise the art of breathing through the nose, because it is provided with a filter to prevent the entrance of harmful germs. In passing through the nose the air is warmed and moistened, and thus, if the correct passage is used, infections are much less liable to develop.

This is one reason why the old-fashioned 'dummy' should not be used by children. It tends to keep the mouth open and it is difficult to keep the dummy sterile. Therefore harmful germs are likely to be introduced into the baby's delicate mouth, throat and internal nasal passages.

How is the air drawn into the body? A very efficient apparatus (Fig. 89) is provided. The ribs are provided with muscles which enable them to be raised at regular intervals. This adds to the internal capacity of the chest. Look at the diagram and you will see that the lungs fill most of the chest cavity; they expand as it increases in size.

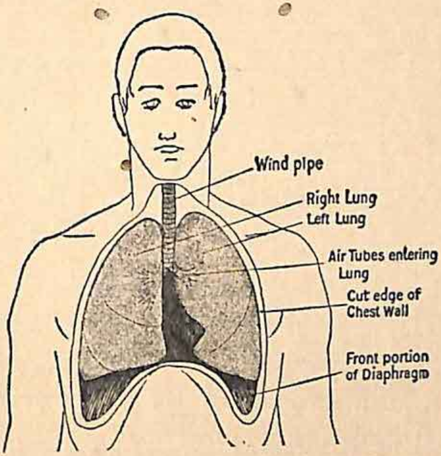

FIG. 89. Diagram showing the position of the Lungs.

A most important part in increasing the cavity of the chest is played by the *diaphragm*, a muscular plate of tissue which divides the chest from the abdomen. When the ribs are raised by the chest muscles the diaphragm is pulled down and it becomes flattened instead of dome-shaped (Fig. 90).

As the chest cavity increases in size something must enter to fill the space, and, because the pressure of the air outside is greater than that of the air inside the lungs, air is drawn through the nose, passes down the windpipe and into the lungs. A model of a pair of lungs may be made with two balloons, a bell-jar and a sheet of rubber (Fig. 91). The diaphragm is represented by the rubber sheet tied over the foot of the bell-jar. When the rubber sheet is pushed in—that is, the diaphragm is made dome-shaped—the pressure inside the bell-jar is increased and the balloons collapse. When the rubber sheet is allowed to become flat the pressure inside is decreased and the balloons expand.

Try to obtain the lungs of a freshly killed rabbit or some other animal so that you can examine their appearance. If the lungs are quite fresh and from a healthy animal, they should be bright red in colour and spongy in appearance.

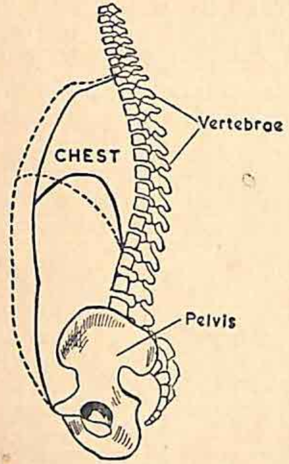

Fig. 90. Inspiration and Expiration. The dotted line shows the effect of full inspiration.

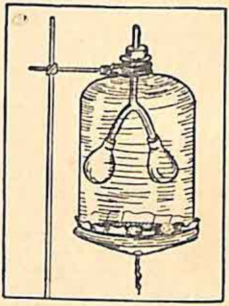

Fig. 91.
Model of Thorax with Lungs and Diaphragm.

## Use of Air in the Lungs

The lungs are like two sponges. The spaces are filled with moist air instead of water and are called *air-spaces*. These tiny air-spaces give the lungs this appearance. On the walls of the air-sacs are tiny blood-vessels called *capillaries*. These are close to the moist air in the lungs.

Some of the capillaries bring to the surface of the air-sacs the blood which has passed through the body and so has been deprived of some of its oxygen. This blood is called de-oxygenated blood. It gives out the carbon dioxide collected during its passage and takes in fresh oxygen from the air sacs, thus becoming oxygenated blood.

The oxygenated blood passes to other capillaries, and through these commences its journey from the lungs to every part of the body.

### How Air leaves the Lungs

The air which has received the carbon dioxide from the blood-stream must now leave the lungs. This is accomplished quite simply. You will notice that after you have taken a breath you cannot hold it indefinitely. The muscles of the ribs and diaphragm relax, whether you wish it or not. The inspiration of air is voluntary, but the expiration is usually involuntary. Of course the expiration of air *may* be voluntary, as when you are blowing up a toy balloon.

As the muscles of ribs and diaphragm relax, the ribs fall down to their original position and the diaphragm becomes dome-shaped once more. This, of course, results in the cavity of the chest becoming reduced in size. The pressure of the air inside the lungs becomes greater than that outside and air is forced out of the lungs.

### Composition of Air leaving the Lungs

As the blood is oxygenated in the lungs some of the oxygen which enters is used up. All the oxygen is not used. We should not be able to live if there were no oxygen at all present. Carbon dioxide is present as a waste product in the air given out by the lungs. How does this come about? This will be explained later in dealing with the passage of the blood through the body.

On analysis it is found that the air leaving the lungs contains roughly 80 per cent. nitrogen, 16 per cent. oxygen and 4 per cent. carbon dioxide.

### Circulation

*Structure of the Blood.* The oxygen taken in by the lungs is circulated throughout the body by means of the blood-stream.

Blood consists of three main constituents.

(1) *The Plasma.* This is a sticky, straw-coloured fluid which passes along the blood-vessels carrying with it the other constituents of the blood.

(2) *The Red Blood Corpuscles* (Fig. 92). These are small, single-celled, disc-shaped bodies only visible under the high powers of the microscope. Their red colour—they are more straw-coloured under the microscope—is due to the presence of a complex compound containing iron called *hæmoglobin.*

Red blood corpuscles are very numerous if the individual is healthy. He should have from 4,000,000 to 5,000,000 in each cubic millimetre of his blood.

The red blood corpuscles of man possess no nuclei, whilst those of the frog have nuclei.

(3) *The White Blood Corpuscles.* These are usually larger than the red blood corpuscles but much less numerous, only about 7000 to the cubic millimetre. They are not so easy to see, but the chance of seeing them is improved if a little *very* dilute acetic acid is added to the drop of blood examined.

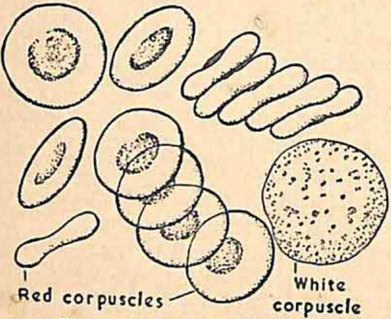

FIG. 92. Blood Corpuscles (*much enlarged*).

**Uses of Blood.** The blood has four main uses in addition to others which you will learn about if you go into the subject more deeply later.

(1) *The plasma or fluid part of the blood is the chief transporting agent.* It carries round with it the red and white blood corpuscles. It also carries the food materials in solution to every part of the body which requires them. It transports waste products in solution from all parts of the body to those special organs which will prepare them for excretion, *e.g.* the kidneys.

(2) *The red blood corpuscles carry the oxygen to all parts of the body.* They are enabled to do this by means of the hæmoglobin present. This hæmoglobin has a great affinity for oxygen. In the lungs it absorbs oxygen and carries it along in the blood-stream. The oxygen is given out and used in the tissues, and the blood takes in the carbon dioxide

formed as a waste product. The carbon dioxide is carried to the lungs where it is passed out in the expired air.

When the hæmoglobin is associated with oxygen it is bright red in colour, but when carbon dioxide has been absorbed and the oxygen lost it becomes bluish-purple. In people with a very fair skin you can often see the blood in the veins just below it; it may appear to be blue in colour.

(3) *The white blood corpuscles fight and destroy harmful germs entering the blood-stream.* When, for example, a finger is injured, harmful germs can readily enter. White blood corpuscles, like soldiers, are rushed to the spot to repel the invader. The corpuscles flow round the germs and destroy them, just as an Amœba flows round and eats the food particles upon which it lives.

(4) *The blood-stream distributes heat throughout the body so that it is kept at an even and suitable temperature.* This is very important. Flushing of the skin on a hot day occurs because the blood passes to the capillaries of the skin and loses heat by becoming cooled at the surface of the body.

*Experiment I.* Prick your finger with a sterile needle. Allow the blood to fall on to a glass slide and note that it coagulates or clots on exposure to air. This is a device to prevent excessive bleeding. You have probably heard that there are certain unfortunate people often known as 'bleeders' because it is practically impossible to stop the flow of blood, even from a small cut. This is because their blood has not the power to clot.

*Experiment II.* Place a drop of fresh blood drawn from your finger on a microscope slide. Mix it with a little very dilute acetic acid. Examine it carefully under low and high powers of the microscope.

You should be able to make out the disc-shaped red blood corpuscles in surface and side view (Fig. 92). You should also be able to see the larger, irregularly shaped white blood corpuscles.

If you cannot make out the white blood corpuscles, take a fresh drop of blood and heat the slide upon which it is placed very gently. Examine again under the microscope. The slight heat may have caused the white corpuscles to move by putting out pseudopodia. White blood corpuscles are capable of independent movement, but red blood corpuscles are carried along in the blood-stream without independent movement.

*Experiment III.* Mix some fresh ox blood with a little sodium citrate to prevent clotting. Bubble a little oxygen through, or shake the tube of blood well with air. The blood becomes bright scarlet.

Bubble carbon dioxide through the blood and the scarlet colour changes to purple. Shake up again with air and the purple colour once more changes to scarlet.

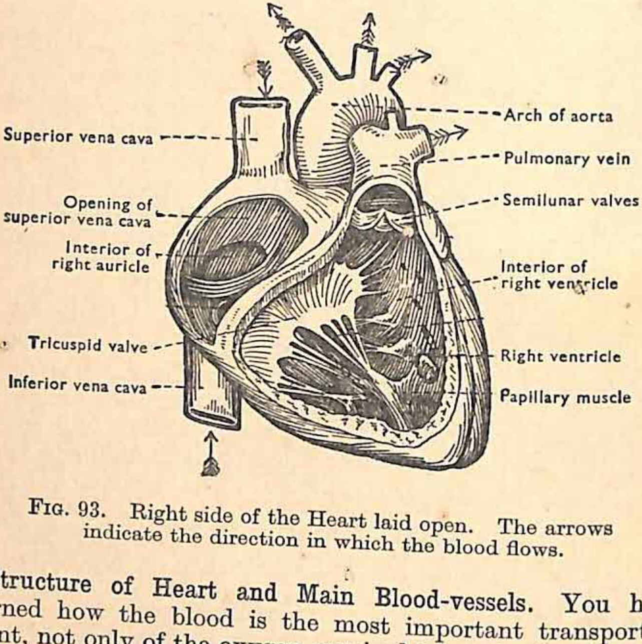

FIG. 93. Right side of the Heart laid open. The arrows indicate the direction in which the blood flows.

**Structure of Heart and Main Blood-vessels.** You have learned how the blood is the most important transporting agent, not only of the oxygen required in respiration, but also of the liquid food material and liquid waste products. We must now investigate the problem of how this transport is carried out.

**Structure of the Heart.** The heart is the pump which forces the blood along through the blood-vessels during its passage through the body. It is roughly triangular in outline, broader at the base and narrowing down towards the apex (Fig. 93). It is divided into four compartments. The two upper are called *auricles* because of their resemblance to ears. The two lower are termed *ventricles*. The right auricle is separated from the right ventricle by the *tricuspid valve*, and the left auricle is separated from the left ventricle by the *mitral valve.* The function of these valves will be explained later in the chapter.

It will be noticed that the walls of the ventricles are much thicker than the walls of the auricles, and that the wall of the left ventricle is much thicker than that of the right ventricle. The reason for this will be obvious when the action of the heart has been described.

**The Blood-vessels.** Blood-vessels may be divided into three groups.

(1) *Veins.* These bring the blood from all parts of the body to the heart. The blood has collected carbon dioxide during its passage through the body, and has lost oxygen; it has darkened in colour. The blood in the veins from the lungs, as we shall see later, is an exception to this rule.

Veins have comparatively thin walls and are provided with valves which only allow the blood to flow towards the heart. If a vein is cut the blood flows out slowly.

(2) *Arteries.* Arteries take the blood away from the heart to all parts of the body. The blood has been replenished with oxygen in the lungs and so is oxygenated blood. The blood in the arteries to the lungs, as we shall see later, is an exception.

The walls of the arteries are thick and more muscular than those of the veins. The blood is therefore pumped along more vigorously and emerges from a cut artery in spurts.

(3) *Capillaries.* Capillaries are very small blood-vessels. As the arteries pass from the heart they divide and, sub-divide and, when they reach the organs, such as liver, kidney or skin, they form very fine, numerous tubes which can carry the blood to every part of the organ. The oxygen is absorbed from the capillaries and carbon dioxide is taken up. The capillaries unite to form small veins, these in their turn unite to form larger veins, and so on until, in the largest veins of all, the blood is carried into the heart.

**Course of the Blood.** Let us follow the course of the blood in its journey through the body (Fig. 94). We shall start with its entry into the heart. The blood enters the heart from the two largest veins in the body. These are called the *superior and inferior venæ cavæ.* The inferior vena cava (V.C.I.) brings the blood from the lower part of the body ($A^2$), and the superior vena cava (V.C.S.) brings it from the upper part of the body ($A^1$).

The blood from the two veins enters the right auricle (R.A.), whence it is pumped to the right ventricle (R.V.). It is prevented from passing backwards into the auricle by the *tricuspid valve*, so called because it consists of three flaps.

From the right ventricle the blood is pumped into a large artery called the *pulmonary artery* (P.A.). It is prevented from passing back into the ventricle by a valve. In the pulmonary artery the blood is carried towards the lungs. The pulmonary artery soon divides into two, one branch going towards each lung. Each branch again divides until the surface of the lung is covered with a network of tiny capillaries (CAPS.).

In the lungs carbon dioxide is given out and a fresh supply of oxygen is absorbed into the blood. Thus the blood in the pulmonary arteries is brought to the lungs for oxygenation. The pulmonary arteries are the only arteries which contain deoxygenated blood.

After oxygenation in the lungs the blood enters a set of capillaries which carry it towards the heart. These capillaries unite until, finally, they form the pulmonary veins (P.V.). The pulmonary veins are the only veins in the body which contain oxygenated blood.

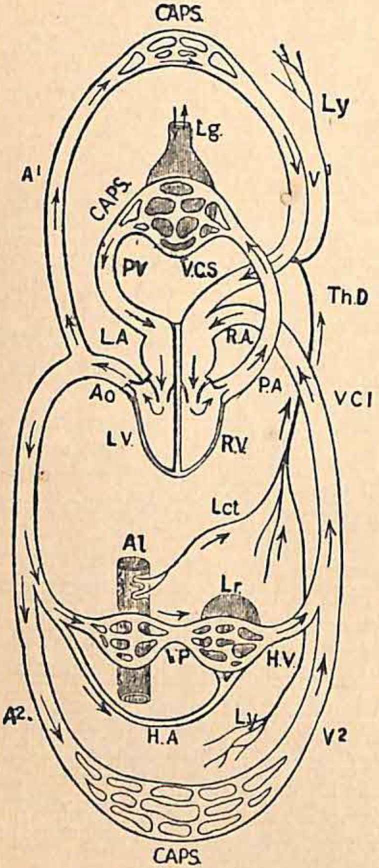

FIG. 94. Diagram of Circulation of the Blood.

The oxygenated blood from the pulmonary veins enters the left auricle. From this it is pumped into the left ventricle, and it is prevented from returning by the *mitral valve*, so called because it resembles a bishop's mitre in shape.

When the tricuspid or the mitral valve does not function properly and allows some of the blood to seep back instead of passing on through the body, a form of heart disease known as 'valvular disease of the heart' is set up. This is often due to certain forms of rheumatism, which cause the valves to become thickened and so unable to function efficiently. It has been remarked that a tendency to rheumatism and heart disease is sometimes found in the same family.

From the left ventricle the blood passes into the largest artery in the body, the *aorta* (Ao.). The entrance to the aorta is provided with a valve like that which closes the entrance to the pulmonary artery, and permits the blood to flow forwards and not back into the left ventricle. The aorta soon divides and the large arteries thus formed branch, until the small capillaries in the skin and organs of the body are formed. The blood passes through the capillaries which, as described before (p. 133), unite to form the veins. Through the veins the deoxygenated blood passes back to the heart and its journey through the body commences once more.

Now you are in a position to understand why the walls of the auricles are much thinner than those of the ventricles, and why the wall of the left ventricle is thicker than that of the right ventricle. The auricles have only to pump the blood into the corresponding ventricles, a very short distance. The right ventricle has to pump the blood to the lungs, a greater distance, and the left ventricle has to pump the blood through the rest of the body, the greatest distance of all. Therefore the wall of the left ventricle must be the strongest because it has the hardest task to perform.

**Use of Oxygen in the Blood.** As in the other animals, the oxygen is used to enable part of the food materials present in the body to oxidise slowly, and so provide the energy necessary for all the processes required to keep the human being in a state of active life.

## CHAPTER XVI

## DISEASES IN PLANTS AND ANIMALS

MAIN CAUSES OF DISEASE IN PLANTS – MALNUTRITION DUE TO LACK OF ESSENTIAL ELEMENTS IN THE SOIL – DISEASES DUE TO PLANT ATTACK – DISEASES DUE TO ANIMAL ATTACK – DISEASES IN MAN – DISEASES DUE TO DEFICIENCY OF ESSENTIAL FOOD-STUFFS – DISEASES DUE TO ENVIRONMENT – DISEASES DUE TO PLANT OR ANIMAL ATTACK

In the last chapter of this book I want to give you some idea of the most common causes of plant and animal diseases. One of the most useful sections of biology is that which gives you some knowledge of how to keep your body healthy, and if you know a little about the main causes of disease it should help you to attain this object. You will probably go to bed more willingly when you are told to do so, if you realise that growing boys and girls need a good amount of sleep if they are to grow up into healthy men and women. It has been said that it is difficult to distinguish between the effects of lack of sleep and lack of food upon children. Both are serious, and lead to stunted and unhealthy growth. You will eat the food you are given with more appreciation if you realise that it has been carefully selected to develop your bodily and mental powers to their fullest extent.

### Diseases in Plants

Let us consider, in the first place, some of the causes of disease in plants. Plants are often much easier to study than animals, and a knowledge of a few of the common diseases to which they are subject may help you to understand animal diseases more fully.

The chief causes of disease in plants are (1) malnutrition, (2) attacks by other plants, (3) attacks by animals.

**Diseases of Plants due to Malnutrition.** The effects of the lack of necessary elements such as nitrogen are very obvious as a rule. The growth of the plant is stunted, and in the end it probably dies. Below are two more examples of this type of disease.

*Iron Deficiency.* Lack of iron affects all green plants. Very small quantities of iron are necessary for the formation of chlorophyll.

The plant becomes pale and yellow instead of a healthy green colour, and grows very tall and thin in its search for sunlight, which is of no effect without the trace of iron.

Sometimes conditions in the soil are such that the plant cannot take in the trace of iron salt it requires. For example, if too much lime is present in the soil it turns the soluble iron salts into a form which cannot be taken in by the plant. This disease is very marked in some regions of England where the fruit trees grow on chalky soil. The health of the trees may be much improved by growing clover and grass among them. This seems to counteract the effect of the lime present.

*Potash Deficiency.* If soluble salts containing potassium are absent a very marked effect is seen in potato plants. The leaves often become deformed and yellowish or bronzed in colour. They often die off early, and are altogether unable to carry on efficiently the important duty of manufacturing food for the plant. Therefore the plant produces a very scanty crop of potatoes or none at all.

The above are just two examples of the important deficiency disease in plants. To keep the land adequately supplied with suitable elements for plant growth, and in the form in which the plant can make use of them, to keep the soil in 'good heart' as it is called, is one of the greatest problems the farmer or gardener has to face.

**Diseases due to other Plants.** Many important diseases of plants are caused by plants which are unable to manufacture food for themselves, and so live as parasites upon other plants which are able to manufacture a food supply. The parasite has no chlorophyll present and this renders it unable to manufacture food. In extreme cases the depredations of the parasite lead to the death of the host plant, and in killing its host the parasite often signs its own death warrant.

*Potato Blight.* This disease almost wiped out the potato crops in Ireland between 1840 and 1850, causing such widespread famine that these years became known as the 'hungry forties.'

The disease is due to a very simple plant called a *fungus.* The fungi are allied to the algæ, such as Spirogyra, in structure, but they differ markedly in their way of life. Fungi do not possess chlorophyll, so they must live at the expense of other plants, or occasionally animals.

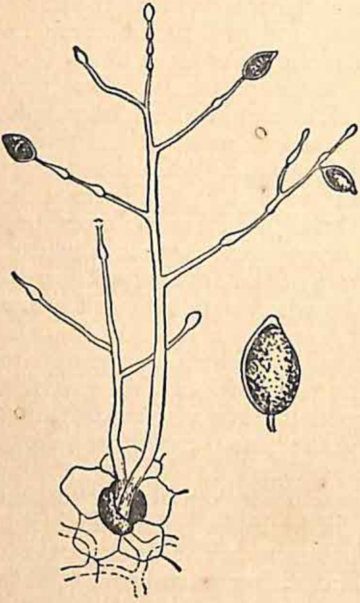

FIG. 95. Potato Blight (*much enlarged*). Spores borne on outgrowths of fungus from the under-surface of the leaf. A single spore on the right.

The particular fungus we are considering lives on the potato plant. It causes dark brown patches on the leaves, and may spread to the stem until the whole plant has become a putrid, evil-smelling mass. A field of potatoes attacked by blight can be detected, because of its odour, quite a distance away.

The fungus is spread by tiny, colourless, pear-shaped spores. These are produced on the under surface of the leaf, on the dark brown patches (Fig. 95); if they fall on the surface of a healthy leaf they may bring about infection. Should any spores be present when the potatoes are dug up they may settle on the tubers and grow during the winter, forming deep, brown, sunken patches (Fig. 96). If infected tubers are planted they carry the disease from one season to the next.

Should you discover a potato with such patches present on it try keeping a piece with a patch on it damp for a little while in a covered glass dish. You may find the delicate, feathery, white fungus appearing. Take a little of the white mass and mount it on a microscope slide in a drop of water. Examine it with the microscope and you will probably see the pear-shaped spores quite easily.

Further information with regard to this disease, and the steps to be taken to guard the potato crop from its ravages, can be obtained from the appropriate Government Department.

**Diseases due to Animals.** Many diseases of plants are due to attacks by animals, particularly by insects. You will probably have seen potatoes eaten by slugs or wireworms.

*The Colorado Beetle.* As an example of this group I have chosen the Colorado beetle, because this little creature has comparatively recently appeared in this country on several occasions, but by the prompt measures taken to exterminate it its spread has so far been prevented.

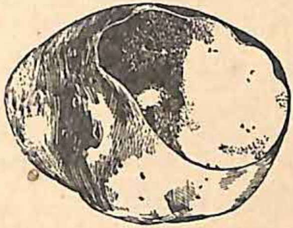

FIG. 96. Potato Blight. Dark brown patches on the skin of the potato and in the flesh.

This little beetle causes so much damage that it may actually wipe out potato crops wholesale.

The beetle is rather a pretty little creature with its coat striped in dark brown and bright yellow. It resembles the ladybird in shape and is about half an inch long (Fig. 97).

The beetle spends the winter buried 10 to 12 inches deep in the soil. In the spring it emerges and flies in search of a potato crop. It feeds on the potato leaves and its eggs are laid there. The grubs which hatch out also feed on the leaves. They are red or reddish brown in colour.

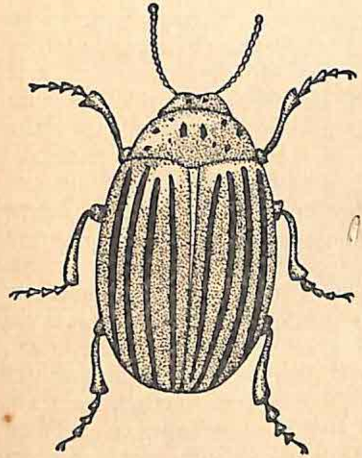

FIG. 97. The Colorado Beetle (*slightly enlarged*).

Beetles and grubs can soon strip a potato plant of all its leaves and so render it incapable of producing a satisfactory crop of potatoes. It is very important that this pest should not obtain a foothold in Britain. As the beetle is so firmly established on the continent of Europe and can fly for miles there is a very grave danger of it crossing the Channel, or it may be introduced in cargoes from America. Any of you whose fathers grow potatoes should keep your eyes open. You may save the country considerable loss should you detect the insect before it commences to breed.

If you find a suspicious beetle or grub on the potato leaves put it into a tin box with a few of the leaves. Do *not* punch holes in the box. Send it, if you live in England, to the Ministry of Agriculture, London, S.W.1, or in Scotland to the Department of Agriculture for Scotland, Edinburgh. Experts will identify the beetle for you and tell you the best steps to take to exterminate it.

## Diseases in Man

In this part of the chapter the purpose is to deal with some of the general causes which lead to the more common diseases which attack mankind, and to give examples. Man is chosen as an example of the animal kingdom, because you are probably more familiar with some of the diseases from which he suffers than with those which attack other animals; indeed, you have probably suffered from some of them yourselves. A comparison is made here with the examples of disease in plants just described, and this will help you to notice that plants and animals have the same general causes of disease.

**Diseases due to lack of Essential Food-stuffs.** As in the plants, disease may be due to the lack of essential foods. This disease is known by the ugly name *starvation*. You have already been told that the body needs proteins for growth and replacement of tissues, carbohydrates, such as sugars and starches, for energy, and fats to provide the heat required. A diet suitable for health, such as most of you are very likely receiving, contains the necessary proportions of those essential food-stuffs which you require to keep you fit.

Apart from the quantity of food, the variety and quality are important. This has already been dealt with in Chapter XIV, p. 118, where it is pointed out that food containing the important vitamins must be included in the diet. The following are examples of diseases due to lack of vitamins.

*Rickets*. This disease used to be more common than it is at the present day. It is a disease which is found in infants and young children, and it may have very serious effects if it should attack a baby when it is beginning to walk. The bones become softened and, as a result, readily distorted.

One condition which the disease may lead to is bow-leg, and another is knock-knee. The bones of the leg, having little strength, are readily deformed by the weight of the child pressing upon them. The teeth are often affected. They appear later than they should, and when they do appear they are soft and decay very quickly.

It had been known for a long time that a rickety condition was found chiefly amongst badly nourished children, the main trouble being that too much bread and other starchy foods had been included in the diet. Faulty feeding was, therefore, considered to be one of the chief causes of the disease, but it is now known that lack of sunshine and lack of exercise also have a part to play. The most important cause was discovered almost by accident.

For years it had been found impossible to rear lion cubs in the London Zoo because they all died of severe rickets, although they were allowed plenty of sunshine. In the Dublin Zoo, on the other hand, where the cubs were reared in darkness they lived and grew well. What was the great difference in the methods practised at the two Zoos? It was found that the cubs in Dublin were given milk, cod-liver oil and pounded bones in addition to raw meat, which was the main diet of the cubs in London. When the new diet was tried out in London the cubs soon became healthy and thrived apace. Doctors therefore concluded that the cause of rickets was a defective diet and not lack of sunshine and fresh air.

Although the sunlight did not help the cubs, doctors soon found that it had a most beneficial effect on children suffering from rickets. This is probably due to the fact that children do not possess thick hairy coats like the lion cubs and therefore sunlight can penetrate their skin much more readily. It was also found that cod-liver oil would cure the disease in children. A third discovery was that artificial sunlight applied by special electric lamps acted in the same way as natural sunlight. Why was it possible to cure rickets in three such different ways? Further research revealed that there is a large quantity of the important vitamin D present in cod-liver oil and halibut-liver oil. The discovery was also made that when the human skin was subjected to natural or artificial sunlight vitamin D was actually formed. The presence of vitamin D in the body enables the latter to make use of bone-forming materials in food, and this explains the cure of rickets by such different means as cod-liver oil and sunlight.

Vitamin D is present in eggs and butter as well as in cod-liver and halibut-liver oil, and recently it has been added to margarine, so that with a properly balanced diet there should be no danger of rickets.

*Scurvy.* This disease used to be prevalent amongst the sailors in the Navy and the Merchant Service during the seventeenth, eighteenth and early nineteenth centuries. An early symptom is softening of the gums, causing them to bleed very easily, and finally the teeth fall out. The patient becomes very weak and depressed.

It was discovered by doctors in the Royal Navy, about 1795, that the use of fresh lemon juice kept the sailors healthy and free from scurvy. The great explorer, Captain Cook, was also aware of this fact, and much of his success in avoiding the disease may have been due to the use of fresh lime juice by his crews. Nowadays it is possible to provide plenty of fresh vegetables and fruit on those ships making long voyages, so that it is not so necessary to provide fresh lime juice for those likely to be long at sea. In any case, ships travel much faster under steam power and can reach port more quickly for supplies.

Research has proved that scurvy is due to the lack of another vitamin, vitamin C, from the diet. It is present in fresh lime juice, and in such everyday articles of food as potatoes, carrots, turnips and fresh fruits. Carrots are particularly rich in this important vitamin, which can be preserved when fruits and vegetables are canned. It is easy to understand why scurvy, in its severe form, is now rarely met with, but mild cases have been known to occur recently, particularly in towns where it is more difficult to obtain fresh fruit and vegetables.

**Diseases due to Environment.** There are many diseases which are due to an unhealthy environment. The continual presence of fouled air may prepare the way for subsequent chest diseases. It is found, for example, that in the neighbourhood of factories where the air contains large amounts of sulphuric acid bronchitis is not uncommon.

The environment, the effects of which lead to disease, may be due to natural causes, or it may be due to conditions brought about by man himself in the course of his daily work.

*Goitre or Derbyshire Neck.* This disease is more common in certain districts, for example the Peak district of Derbyshire. The goitre takes the form of a swelling in the neck, hence the popular name for it.

The disease is caused by deficient intake of iodine in food and drinking water. Cures have been affected by removing the patient to another district. The addition of iodine to the food and drinking water of the inhabitants has prevented the occurrence of the disease. Table salt with iodine added to it, 'iodised salt' as it has been called, is also used to prevent the occurrence of goitre.

*Silicosis.* This disease is prevalent amongst stone-cutters and other workers who are subjected to an atmosphere containing silica dust. A condition of the lungs is caused which may render the patient liable to the development of tuberculosis. Modern methods of preventing the dust rising and its entry into the lungs of the worker while breathing have done much to make this disease less common than it was formerly.

**Diseases due to Plants.** Diseases belonging to this group are caused by plants, usually very tiny, which depend for their food supply upon the unfortunate victim of their attack.

The plants causing disease include that very large and important group commonly known as germs or microbes, but scientifically as *bacteria*. You may very likely have suffered from diseases caused by bacteria yourself. Many diseases from which children are liable to suffer are caused by these ubiquitous pests. Such ailments as diphtheria and whooping-cough are due to attack by bacteria.

The so-called germ is a very tiny plant. Many thousands would probably find room on a minute speck of dust. Many are only about one twenty-five thousandth of an inch in length. They are often rod-like in shape, though some are like very tiny balls. Indeed there are many different kinds, and each kind may behave in a very different way from all the others. Some kinds are useful and break down dead and decaying plant and animal remains, rendering them suitable food for plants once more. Others, as stated above, cause diseases of man, other animals and plants.

These tiny plants reproduce in the simple way described for amœba. The cell divides into two daughter cells, and these can again divide until, at the end of twenty-four hours, a single germ has given rise to many million. Herein lies their great danger. A great army can rapidly be produced to carry out the attack. Some bacteria are able to form thick-walled cells, *spores*, which are able to survive after being boiled, or after drying for months or years. Each spore can again develop into a germ after it has alighted where it can obtain a suitable food supply. The germ which causes that dread disease, tetanus or lock-jaw, is one which can form spores. In one hospital ward these spores were found alive six months after the last patient suffering from lock-jaw had left.

Some of the diseases due to bacteria can be transmitted from one person to another, so a sufferer from any one of these should be isolated as far as possible to prevent the spread of infection. That is why isolation hospitals, specially prepared to deal with such cases, are so useful. It is also the reason that cleanliness is so important. Germs of the most common *infectious diseases*, as they are called, are present everywhere awaiting a suitable host, perhaps yourself, in which to develop. How can you take steps to render yourself an unsuitable host? In the first place, cleanliness will ensure that many of the germs which may have alighted upon you are removed and probably destroyed before they can do any serious harm. In the second place, the bodily health should be kept in a satisfactory condition by the use of good food, sufficient exercise, fresh air and sleep. In many infectious diseases, for example the common cold, it is often those in a poor state of health who are attacked, and, in any case, if the general health is good the disease will be more readily combated.

If there is an epidemic of an infectious disease, even of the common cold, it is wise to avoid such crowded places as picture houses, as it is in such surroundings that infection is most readily passed on from one individual to another—in the case of the common cold, for example, by coughing and sneezing.

The infectious or contagious diseases have been very extensively investigated by the medical profession, and not only cures but means of prevention have been discovered in a number of cases. The most famous example of prevention is the discovery by Jenner, an English doctor who lived about the beginning of the nineteenth century, of vaccination against smallpox. It had been known for a long time that if one had suffered from an attack of smallpox it was very unlikely that one would contract the disease again. Indeed, since the disease at that time was distressingly prevalent, many wealthy people would arrange to be infected with the disease so that they could be laid up at a time convenient to themselves. The famous Catherine the Great of Russia sent for an English doctor named Dimsdale to treat her in this way. He was successful; Catherine duly contracted smallpox and, fortunately, recovered from it. In her gratitude she rewarded Dr Dimsdale very handsomely. He was made a Baron, given a sum of £10,000 and a pension of £500 a year for life.

Why did an attack of smallpox render one immune from the disease if one recovered from it? It has been discovered by doctors that when the body is attacked by a disease like smallpox it immediately rushes up its defences, substances called antibodies, which fight the disease and, if sufficiently strong, conquer it. Now in certain diseases, of which smallpox is one, such a quantity of these antibodies is made that, if the attack is comparatively light, there is sufficient left over to protect the body against the particular disease for quite a long period. Hence arose the practice of infecting the individual with the disease in the hope that the attack would turn out to be a slight one, but sufficient to render the patient immune for many years to come.

Jenner realised that there was a great danger in infecting anyone with such a serious disease as smallpox. He had noticed that dairymaids and other workers whose duties included the milking of cows seldom suffered from smallpox, and if any one of them had an attack it was only very slight. On investigation he found that many cows suffered from swellings on their udders which could infect the workers with a disease very like smallpox, called cowpox, through cracks on fingers or hands. He considered that cowpox was just a mild form of smallpox and that it would be much safer to infect with this form of the disease. His experiments proved successful, and led to the almost universal practice of vaccination, a practice which must have saved millions from the unsightly disfigurements caused by smallpox. Public health measures and personal cleanliness have also played their part in the prevention of this disease.

Another marvellous advance in the prevention of infectious diseases has been made in the case of diphtheria. A German scientist named Behring discovered that he could infect horses with diphtheria and that the horse did not take the disease so badly as a human being. Nevertheless it developed the antibodies in its blood in great quantity, and from this blood a clear fluid could be obtained called a *serum*. This fluid contained the antibodies, and when injected into a sufferer from the disease it checked the latter, and almost invariably the patient recovered. Recently medical science has gone still further. A test, called the Schick test, is used which actually shows whether the individual is susceptible to diphtheria or not. In some of the large towns many of the children have been tested in this way. If it is proved that the child is liable to contract diphtheria he can be given an injection which will render him almost immune to the disease. The injection causes the child no serious inconvenience, and it is well worth any slight discomfort to ensure safety.

Diseases due to Animals. Several comparatively well-known diseases are due to attack by animals. The following two examples will be sufficient to illustrate this group of diseases.

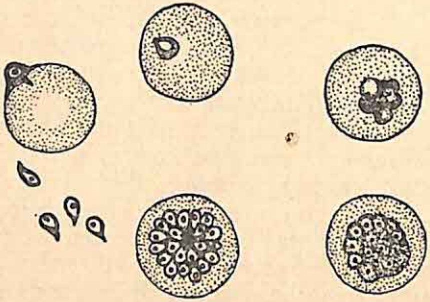

FIG. 98. Stages in development of the Malaria organism in the red blood corpuscles (*much enlarged*). The free stage in the blood is shown on the left.

*Malaria*. This disease does not usually trouble us in this country, but it has been responsible for much disaster in other lands. The ravages of a virulent type of malaria probably accounted for the sudden deaths of the soldiers of the entire Assyrian army which, under Sennacherib, was besieging the town of Jerusalem in the time of Hezekiah. Malaria caused the collapse of the Darien scheme to develop Panama, and so brought ruin to many Scottish homes at the beginning of the eighteenth century.

Malaria is due to the attack of a small, one-celled animal (Fig. 98) which, during part of its life, resembles amœba. It lives in the red blood corpuscles, and its presence causes the distressing symptoms of fever so well known to those who have had to live in the more unhealthy districts of the tropics. How does this little organism get into the blood-stream?

Sir Ronald Ross, a famous Scotsman, was the first to discover the answer to this question. He found that the parasite was present in the stomach of a certain kind of mosquito which feeds by sucking the blood of man. When the mosquito bites, some of its saliva gets into the victim's blood and carries with it the parasite, which has passed from the stomach to the salivary glands of the insect.

Since the discovery made by Ross malaria has been stamped out in many regions—for example the low-lying Campagna near Rome and the marshes round Salonica. The methods adopted to accomplish this are based on an investigation of the breeding habits of the mosquito. It lays its eggs on stagnant water. These hatch out into free-swimming larvae which soon change into winged mosquitos. The larvæ breathe through small tubes attached to their hinder end (Fig. 99). All that is necessary is to get rid of the stagnant water in the neighbourhood so that the mosquito will have nowhere to breed. If the water cannot be drained away, paraffin poured on the surface kills the larvæ by suffocating them, as it chokes the breathing tubes through which they get their supply of air.

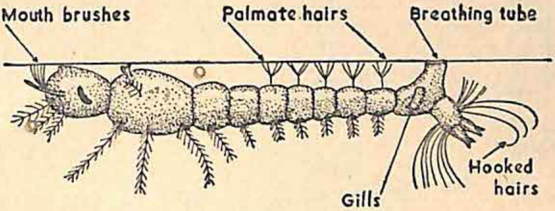

FIG. 99. The Mosquito Larva (*slightly enlarged*).

*Tapeworm.* This disease used to be dreaded much more than it is now. It has been found very easy to prevent its spread, but, when once contracted, the tapeworm is very difficult to get rid of.

The tapeworm, like the earthworm, is made up of segments, about 850 in number. These are white in colour and flat in shape, so forming a ribbon-like piece of tape, hence the name. The head of the tapeworm is provided with a number of hooks which attach it to the wall of the intestine in which it lives; it is smaller in size than the segments (Fig. 100). As the segments become ripe they are shed and pass out with the fæces.

The ripe segments contain a great number of eggs, as many as 30,000, and these may infect the food of the pig. With the food they enter the stomach of the pig and from there infect the flesh, forming small cysts in the muscles and thus giving rise to 'measly' pork (Fig. 101). When this is eaten by man the tapeworm develops in his intestine, and so the life-story is repeated once more.

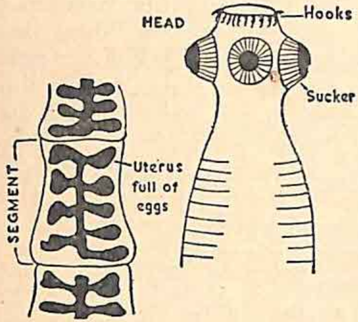

Fig. 100. The Tapeworm.

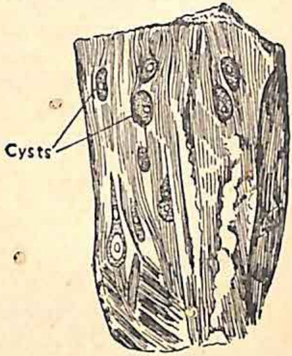

Fig. 101. Measly Pork containing tapeworm cysts.

The disease can be avoided by rejecting measly pork and by seeing that all pork eaten is well cooked. Meat must now be passed by an inspector as fit for human consumption, and this is a safeguard against measly pork being exposed for sale.

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